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SOMMERVILLE

H. W. Turnbull

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BIBLIOGRAPHY

OF

NON-EUCLIDEAN GEOMETRY

including

The Theory of Parallels, the Foundations of Geometry,
and Space of n Dimensions.

BY

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INTRODUCTION.

PERHAPS the most characteristic feature of the present trend of mathematical research is the close attention which has been directed to the logical foundations of the science and its relation to psychology. The first stimulus to these investigations was given by an examination of the axioms of geometry, Fifty years ago these axioms, with one exception, were accepted as intuitive truths, whose denial would have been absurd. It is now being recognised that they are arbitrary and convenient assumptions, which it would be absurd to attempt to prove since they are not even necessarily true. The one exception, the one "axiom" which appeared to lack intuitive character, was the so-called "parallel-axiom." Countless attempts were made to deduce it from the other "intuitive" axioms, but at length, by the bold stroke of denying it altogether, its true arbitrariness was discovered, and a new geometry, "absolute" or "non-euclidean" geometry, was developed. It was shown that, though differing markedly from the classical system of Euclid, this geometry is self-consistent, and forms a general system of which ordinary geometry is merely a special case. As deductive systems it appears therefore that these geometries are equally valid and there is no question of the truth or falsity of one or the other. When geometry is applied to the actual measuring of concrete objects it becomes an applied science, and here again it appeared that there was no physical test by which the truth of the euclidean system could be established, for this would involve an infinite series of observations. Considerations such as these have now been brought to bear upon the other axioms, both of geometry and of arithmetic, and geometry has become more and more a purely deductive science, while mathematics appears as a development of logic.

The subject of non-euclidean geometry has been discovered, or at least partially so, on several distinct occasions, but it is always associated with the names of LOBACHEVSKIJ (Professor at Kazan) and BOLYAI JÁNOS (a Hungarian student), whose first works on the subject appeared about 1830. The subject did not really begin to be studied seriously, however, until about 1870, when HOÜEL's French translations of Lobachevskij's and Bolyai's somewhat inaccessible memoirs appeared. Since that time the interest in the subject has steadily increased, until at the present time it is to be considered, both from its intrinsic interest and the importance of its applications, especially in Function-theory, as much a branch of mathematics as, for example, Quaternions, and courses of lectures in it are regularly given in some of the German and Italian Universities. The study of space of higher dimensions begins about the same time, for, except for a few scattered references in KANT and LEIBNIZ, there is no explicit mention of the subject until CAYLEY's classical paper of 1843, and it did not become to any extent a subject of study until 35 years later. It now proves a most fertile field of research. In the hands of the Italian school it has been shown to possess a high intrinsic interest, while its usefulness in providing a convenient and succinct language for stating analytical results and also a means of discovering new theorems is not to be ignored.

Thirty years ago Professor G. B. HALSTED published the first bibliography of non-euclidean geometry and hyperspace. At that time this joint subject was at an interesting stage. HELMHOLTZ was popularising non-euclidean geometry in England and in Germany, and the interest of philosophers was roused to rescue their favourite example of "necessary truths" from the general attack of scepticism. Space of n dimensions was just emerging as a branch of geometry capable of rigorous treatment and was attaining an unfortunate popularity in the hands of the spiritualists. Both subjects were surrounded by a mysticism which can scarcely yet be said to be entirely dissipated.

Since the appearance of Halsted's bibliography the amount of literature published on the subject is enormous, but three other bibliographies have sought to cope with the materials. These are: STÄCKEL and ENGEL on the theory of parallels or pre-noneuclidean writings, SCHLEGEL on space of n dimensions, and BONOLA on the foundations of geometry, excluding n dimensions. Halsted's bibliography is a model of its kind. It includes nearly 200 titles of works relating to non-euclidean geometry and space of n dimensions from about 1830 to 1879. The order is mainly chronological, but all the works by the same author are collected together. Short notes appended to the chief works form a valuable feature. The other three works are non-overlapping, with the exception of a few titles relating to non-euclidean geometry of n dimensions. The bibliography of Stäckel and Engel on the Theory of Parallels is a chronological list of nearly 300 titles from 1482 to 1837, with careful references to sources, and is almost complete. It occurs as an Appendix to the "Theorie der Parallellinien," a very valuable contribution to the early history of non-euclidean geometry. Schlegel's list of works on n dimensions accompanies a report on the subject which supplies the place of Halsted's notes. It contains about 400 titles, arranged alphabetically under the authors. The bibliography of Bonola, whose recent death at the early age of 36 is a great loss to science, is the most extensive which has hitherto appeared. It was published first in serial form from 1899 to 1902 and was then collected in the Bolyai-Festschrift. It contains over 900 titles chronologically arranged from 1839 to 1902, with an index of authors. There is a classification under the headings, Elementary geometry, Metrical and differential geometry, Group-theory, Projective geometry, Finite distances, Vectorial methods, Mechanics and physics, General expositions, Philosophy and history. Works under the last heading are collected in a separate list, while the other classes are denoted by letters which are placed after the titles. There is no Subject Index.

The present work was begun about nine years ago. It was intended as a continuation of Halsted's bibliography, but it soon became evident that the growth of the subject rendered such diffuse treatment practically impossible, and short abstracts of the works would have to be dispensed with. The plan actually adopted is explained in detail below. The object is to produce as far as possible a complete repository of the titles of all works from the earliest times up to the present which deal with the extended conception of space, and to form a guide to the literature in an easily accessible form. It includes the theory of parallels, non-euclidean geometry, the foundations of geometry, and space of n dimensions. Works on the foundations of mathematics or arithmetic are excluded except in so far as they have an explicit reference to geometry. The foundation of arithmetic is collateral with the foundation of geometry and is concerned with many analogous questions. As instances of the close connection which exists between their lines of develop-

ment one may mention finite geometries and galois fields, non-archimedian geometries and non-archimedian algebras. A joint treatment of these subjects might thus have appeared desirable, but in 1904 the International Association for Promoting the Study of Quaternions published an extensive bibliography, prepared by Dr. Alexander MACFARLANE, which is being continued and extended on lines which will embrace Universal Algebra and questions relating to the foundations of number. The recently created subject of Point Groups, due to G. CANTOR, is on the borderland between arithmetic and geometry, and many references will be found to it. A more complete bibliography of this subject will be found in the treatise of Dr. and Mrs. YOUNG, 1906.

The total number of titles in the present work is about 4,000, divided roughly as follows: theory of parallels, 700; non-euclidean geometry and the foundations of geometry, 1,600; n dimensions, 1,800. An analysis of the nationalities of the authors (excluding mere reviewers and translators) is approximately as follows: German, 460; French, 230; Italian, 220; British, 160; American, 90; Russian and Polish, 80; Dutch, 35; Hungarian, Bohemian, Croatian, &c., 35; Scandinavian, 35. No attempt is made here to distinguish between German and Austrian, French and Belgian, while the Swiss are also included among these. An analysis of the number of works (including translations), published in various languages, is given on the following page.

The work is arranged in three parts, as in RICCARDI'S "Euclidean Bibliography": I. Chronological Catalogue; II. Subject Index; III. Author Index. The explanations of the arrangements of these parts are given in order below. The Subject Index is a distinguishing feature of the present work, and is an absolute necessity when the amount of material is so great. It contains about 600 headings and sub-headings, and over 5,000 references.

In addition to the bibliographies already mentioned, the principal sources have been the "Jahrbuch," the "Revue Semestrielle" and the "International Catalogue." The "Bibliographie der Deutschen Naturwissenschaftlichen Litteratur," and corresponding French and Russian works, have not been consulted; but as these are compiled in conjunction with the "International Catalogue," they could only give assistance for the most recent literature which is not yet included in the "International Catalogue." An extensive review of bibliographical aids to mathematics is given by WÖLFFING (see below). The following is a list of the sources which have been used. Those marked with an asterisk are to be found in the Chronological Catalogue. The letters in italics are the symbols under which they are referred to in the Chronological Catalogue:—

Theory of Parallels.

- | | | | |
|--------------------|---|---------------------|----------|
| *Voigt, J. H. | Diss. math. | 1789. | V. |
| Murhardt, F. W. G. | Litteratur der mathematischen Wissenschaften. | Leipzig. | |
| | Bd. I, 1797. Bd. II, 1798. | | M. |
| Müller, J. W. | Auserlesene mathematische Bibliothek. | Nürnberg. 1820. pp. | |
| | 229-234. | | J. W. M. |
| *Camerer, J. W. | Euclidis elementorum libri sex. | 1824. | C. |
| *Jacobi, C. F. A. | De undecimo Euclidis axiome. | 1824. | J. |
| *Thompson, T. | Perronet. Geometry without axioms. | 5th ed. 1834. | P. T. |

	Theory of Parallels.					Foundations of Geom. and Non-Geom. Geom.					n Dimensions.					Totals.					Grand Totals.			
	To 1870.	1871-80.	1881-90.	1891-1900.	1901-10.	Total.	To 1870.	1871-80.	1881-90.	1891-1900.	1901-10.	Total.	To 1870.	1871-80.	1881-90.	1891-1900.	1901-10.							
German	152	16	8	11	14	201	36	69	53	110	206	474	14	66	135	142	146	503	194	143	188	259	365	1,149
French	140	11	16	37	35	239	26	15	36	148	157	382	6	15	34	124	117	296	170	35	83	302	294	884
Italian	24	8	7	4	9	52	15	33	35	83	97	263	3	5	141	171	225	545	40	45	182	255	326	848
English	68	4	9	4	12	97	12	29	27	94	152	314	13	33	56	103	166	371	90	62	86	177	308	723
Dutch	3	—	1	—	—	4	—	—	—	1	7	8	—	—	—	16	53	69	3	—	1	16	59	79
Spanish and Portuguese	2	—	—	—	1	3	—	—	2	12	6	20	—	—	1	2	2	5	2	—	3	14	8	27
Danish and Norwegian	—	—	—	—	—	—	—	—	4	2	9	15	—	—	1	1	4	6	—	—	5	3	13	21
Swedish	5	1	—	—	—	6	—	—	2	1	—	3	—	—	2	—	—	2	5	1	4	1	—	11
Russian	2	1	—	1	6	10	6	—	2	43	31	82	1	1	1	6	6	14	8	1	2	47	41	99
Polish	—	—	—	—	—	—	—	2	1	6	4	13	—	1	3	1	6	11	—	2	4	7	9	22
Ruthenian	—	—	—	—	—	—	—	—	—	—	2	2	—	—	—	—	—	—	—	—	—	—	2	2
Magyar	—	—	—	1	—	1	1	1	2	8	22	34	—	—	—	—	2	2	1	1	2	9	24	37
Czech	—	—	—	—	—	—	—	—	—	3	3	6	—	—	—	—	—	2	—	—	—	3	3	6
Croatian	—	—	—	—	—	—	—	—	—	—	7	7	—	—	—	—	2	2	—	—	—	—	9	1
Rumanian	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
Latin	64	—	—	2	—	66	7	—	—	2	3	12	3	—	—	—	1	4	72	—	—	4	—	80
Greek	6	—	—	—	—	—	2	—	—	—	—	2	1	—	—	—	—	1	9	—	—	—	—	9
Arabic	4	—	—	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	4
Sanskrit	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Esperanto	—	—	—	—	1	1	—	—	—	—	2	2	—	—	—	—	—	1	—	—	—	—	4	4
Totals	470	41	41	61	79	692	105	149	164	513	708	1,639	41	120	374	566	731	1,832	598	290	560	1,098	1,470	4,016

- ***Hill**, C. J. *Conatus theoriæ parallelarum stabiliendi*. 1835. *Hill*
- ***Sohncke**, L. A. Article "Parallel." 1838. *S.*
- *Bibliotheca mathematica*. Verzeichniss der Bücher über die gesammten Zweige der Mathematik, welche in Deutschland und Auslande vom Jahre 1830 bis Mitte des Jahres 1854 erschienen sind. Leipzig. 1854. *S. Bibl.*
- ***Hoffmann**, J. J. I. *Das eilfte Axiom des Euclides*. 1859. *Hoff.*
- ***Riccardi**, P. *Saggio di una bibliografia euclidea*. 1887. *R.*
- ***Stäckel**, P. and **F. Engel**. *Theorie der Parallelinien*, 1895; and Supplement. *See* STÄCKEL, 1895 and 1899¹. *S. & E.*
- ***Heath**, T. L. *The 13 books of Euclid's Elements*. 1908. *Heath.*

General.

- Jahrbuch über die Fortschritte der Mathematik*. Berlin. Bd. 1 (Jhrg. 1868) 1871, 2 (1869-70) 1873, 3 (1871) 1874, &c., 24 (1892) 1895, 25 (1893-4) 1897, 26 (1895) 1898, &c., 39 (1908) 1911. *F.*
- Revue semestrielle des publications mathématiques, rédigée sous les auspices de la Société Mathématique d'Amsterdam*. Amsterdam. Vol. 1 (1893), &c., 19, (1911). *Tables des matières*, 1-5 (1893-7), 6-10 (1898-1902). *R. S. P. M.*
- Catalogue of scientific papers compiled and published by the Royal Society of London*. London. Vols. 1-6 (1800-1863) 1867-8-9-70-1-2, Vols. 7-8 (1864-1873) 1877-9, Vols. 9-11 (1874-1883) 1891-4-6, Suppl. Vol. 12 (1800-1883) 1902. [In progress of completion up to 1900.] *R. S. Cat.*
- Royal Society of London Catalogue of scientific papers 1800-1900. Subject-Index*. Vol. I. *Pure Mathematics*. Cambridge: Univ. Press. *R. S. Cat.*
- International Catalogue of scientific literature*. Published for the International Council by the Royal Society of London. (A) *Mathematics*. London. Vol. 1 (Year 1901) 1902, &c., 9 (to June 1910) 1911. *Int. Cat.*
- Poggendorff**, J. C. *Bibliographisch-literarisches Handwörterbuch zur Geschichte der exacten Wissenschaften*. Leipzig. Bd. I, II (A-L, M-Z) 1863, III (1858-1883) 1898, IV (1883 to date) 1904. *P.*
- Wölffing**, E. *Mathematischer Bücherschatz*. Systematisches Verzeichnis der wichtigsten Deutschen und ausländischen Lehrbücher und Monographien des 19. Jahrhunderts [d.h. die nicht-periodische math. Literatur 1801-1900] auf dem Gebiete der mathematischen Wissenschaften. In 2 Teilen. I. Teil: *Reine Mathematik*. Mit einer Einleitung: *Kritische Übersicht über die bibliographischen Hilfsmittel der Mathematik*. Leipzig: Teubner. pp. xxxvi + 416. (Abh. Gesch. math. Wiss., XVI, 1.) *Wö.*
- [Especially: 2, *Philos. der Math.*; 139, *Prinz. der Geom.*; 140, *Parallelen-theorie*; 141, *Nichteuklidische Geom.*; 142, *n-dimensionale Geom.*]
- ***Halsted**, G. B. *Bibliography of hyperspace*. 1878. *H.*
- ***Schlegel**, V. [Bibliography of n dimensions.] 1886¹ and 1900. *Schlg.*
- ***Bonola**, R. *Bibliografia sui fondamenti della geometria*. 1899. *B.*
- Circolo matematico di Palermo*. *Rendiconti*. Parte 2^a, t. 2-20.
- *Supplemento ai Rendiconti*, 1 (1906), &c., 6 (1911).
- *Annuario biografico*.

To the above list should be added publishers' circulars and catalogues, especially that of B. G. Teubner in Leipzig. The English publishers' catalogues are robbed of much of their usefulness by the absence of the dates of publication.

I. THE CHRONOLOGICAL CATALOGUE.

The titles in each year are arranged alphabetically according to the authors. Anonymous works are placed under Anon. at the end of each year. When a work is in several volumes, published in different years, it is to be found under the first year of publication. Later editions and translations are indicated along with the first edition; translations, and later editions which contain some essential change, are also to be found separately entered under their own years. Collaborations are entered under the name of the author who is first mentioned. Reviews are referred to below the title. When the review is itself entered in the Chronological Catalogue the reference is by the name of the reviewer in small capitals followed by the date. The source of most of the information regarding reviews is the "*Revue semestrielle*." The titles of works in Magyar and Slavonic languages are given in the original, when this has been accessible, and also in English translation. English translations of titles in Dutch, Spanish, Danish, &c., will be found in the Author Index. Occasionally a title is expanded to make it more descriptive; all such additions are enclosed within square brackets [].

The classification is indicated in square brackets after the title.

The names of journals are abbreviated according to the system adopted for the "*International Catalogue*." Figures in heavy type are volume-numbers or years, the figures in brackets which sometimes precede these are the numbers of the series, the figures after the volume-numbers are the page-numbers.

There are numerous references from one title to another which is closely connected with it. When the name of an author is in small capitals, simply followed by the date, as CHASLES, 1856, this indicates a reference to the Chronological Catalogue under the year and author mentioned. The sign $\rightarrow$ indicates a reference to the Appendix, where some additional information is given which has been received too late for insertion without over-running of the pages.

References to bibliographical sources have only been given in cases of discrepancies among the authorities. A key to the few references which occur is given in the list of bibliographical sources above. A very few titles are marked with an asterisk (*) as having been personally verified. For the great majority it has not been thought necessary to indicate the authority. To do this properly, as Stäckel and Engel have done for the theory of parallels, would require a search through all bibliographies to find when a particular work was first mentioned as having reference to the subject.

The prices of independently published works are given when known. When a work is issued unbound the price given generally refers to this form. The prices have been obtained from publishers' catalogues, catalogues of second-hand books ("*Antiquariats-Kataloge*"), Wölffing's "*Bücherschatz*," and various general bibliographies compiled in the interests of the book trade.

II. THE SUBJECT INDEX.

The classification adopted is that of the "*Index du répertoire bibliographique*," the new edition of which, in 1908, was specially extended to give adequate recognition to non-euclidean geometry and space of n dimensions. About 170 of the headings and sub-headings of the index have been utilised, but it has been found advisable to introduce a few additional headings. The most important of these are the following: Sub-classes 6 and 7 are added

to M⁶ and M⁷ corresponding respectively to M²⁷ and to M¹⁴, M²⁸ and M⁵⁴. "Concrete representations of non-euclidean geometry," including the Cayley-Klein representation, are grouped under a new section Q1e; this leaves Q1d entirely free for the more recent non-euclidean geometries; Q2 is sub-divided, as it still forms too large a section; V2b is appropriated for historical questions, and is sub-divided.

A number of other sub-divisions are introduced on the analogy of the older parts of the "Index." All works dealing with special topics in non-euclidean geometry, whether hyperbolic or elliptic, are put under Q1, which is sub-divided under the headings K to P. This leaves Q1b and Q1c for works which deal specially with hyperbolic and elliptic geometry respectively. There are in addition a large number of sub-headings not characterised by any distinctive number or letter other than the general symbol under which they are placed.

A reference to the List of Principal Headings will show the general arrangement. Any particular topic can be found by consulting the Alphabetical Index of Subjects.

The references are to the year and the author. Figures in brackets after an author's name refer to the number of the paper by that author in the particular year. There is no reference to translations.

The question of indicating the relative importance of the various references, as is done in Baedeker's guides, was considered, but has been abandoned. To anyone familiar with the subject the name of the author itself will sometimes give a sufficient indication. For the benefit especially of those who are approaching the subject for the first time a list of general expositions of non-euclidean geometry is given under Q1, while under V1a₇ and V1a₈ will be found a list of treatises on geometry of n dimensions, non-euclidean geometry, and the foundations of geometry.

III. THE AUTHOR INDEX.

The names of the authors are, as far as possible, given in full, but the forenames which are not habitually used by the author are enclosed within brackets. This does not apply to names of which the initial letter is habitually used by the author. Russian names are transliterated according to the system adopted for the "International Catalogue."

For the alphabetic order ä, ö, ü are considered as ae, oe, ue. The Magyar ő and ű are equivalent to ö and ü with the addition of an acute accent. Other diacritical marks, and the Arabic prefix al (an, at, &c.), are ignored in alphabetisation.

Names with prepositional prefixes are catalogued under the name following the prefix. These prefixes are d', da, de, von, van. English names with such prefixes are, however, catalogued under the prefix, as De Morgan.

Names with the article prefixed are catalogued under the article. These prefixes are Dal, Del, Dell', Della, Des, Du, La, Le. French names with prefix de La are to be found under La.

The numbers within brackets, following the name of an author, are the dates of his birth and death.

The sources for the full names of authors and their dates are Poggendorff, the "Annuario" of the Circolo matematico di Palermo, scattered obituaries, and, to a smaller extent, the "Deutscher Universitäts-Kalender," "Minerva," Barth's "Adressbuch," "Who's Who," and similar compilations.

In the Author Index the titles are very much abbreviated, the full titles being given in the Chronological Catalogue. Only the titles of works in English, French, German, Italian and Latin are given in the original language; others are translated into English, the name of the original language being enclosed within brackets.

References to translations or later editions, when these are separately entered in the Chronological Catalogue, are by dates following that of the original work, accompanied by the name of the language.

Translations, reviews, &c., which are entered in the Chronological Catalogue under the name of the original author, are referred to also under the name of the translator, &c., the name of the original author being given in small capitals, followed by the date. Collaborations are entered under both authors, with the name of the collaborator. When the work is entered in the Chronological Catalogue under the name of the collaborator, his name is given in small capitals. In all cases the printing of an author's name in small capitals indicates a reference to that author in the Chronological Catalogue.

Dates of independently published works are printed in heavy type.

E_n (Espace), R_n (Raum), S_n (Space, Spazio) mean "Space of n dimensions."

While great care has been taken in the compilation of the work, it is inevitable that mistakes and omissions should occur. Any notifications of such errors will be gratefully received. No attempt has been made to obtain titles of works later than 1910, and the list for 1910 itself appears to be very defective. The Appendix contains titles which have been received too late for insertion in the body of the work.

My grateful thanks are due to the University Court of St. Andrews for undertaking the publication of this book, and acknowledgment must also be made to the staff of Messrs. Harrison and Sons for the care and attention which they have given to the printing.

D. M. Y. SOMMERVILLE.

*The University, St. Andrews,
September, 1911.*

PART I.

CHRONOLOGICAL CATALOGUE.

4th CENTURY B.C.

- Aristotle.** 1. [Axiom equivalent to Euc. Post. V.] De caelo, I, 5, 271 b¹28. [Q1aα]
[Referred to by Proclus (ed. Friedlein), p. 371 (10).]
- 2. [On the nature and definition of the point.] [Q1a]
De caelo, II, 13, 296 a 17; III, 1, 299 a 30, 300 a 14.
Physica, IV, 1, 209 a 11; IV, 8, 215 b 19; IV, 11, 220 a 1-21; VI, 1,
231 b 6 sqq.
De gen. et corr., I, 2, 317 a 10.
De anima, I, 4, 409 a 4.
Metaph., 1016 b 24, 992 a 20.
Topica, VI, 4, 141 b 21. [The references are to Bekker's ed.].
- Plato.** [On the definition of a straight line.] [Q1a]
Parmenides, 137 E.

1st CENTURY B.C.

- Geminus.** [On parallels.] [Q1aα]
[Quoted by Proclus (ed. Friedlein), pp. 176-177, 178-182, 183-184, 192,
355-356.]
- Posidonius.** [Definition of parallels.] [Q1aα]
[Quoted by Proclus (Ed. Friedlein, p. 176) on authority of Geminus.]

2nd CENTURY.

- Ptolemy of Alexandria.** 1. [Proof that there cannot be more than three dimensions
in space.] [V1d]
[Mentioned by W. W. R. Ball in his History, 4th ed., 1908, p. 99.]
- 2. [About the meeting of straight lines produced from angles less
than two right angles.] [Q1aα]
[Mentioned by Proclus in his Commentaries, 1553 ed., p. 95 ff;
Friedlein ed., pp. 191, 362-363, 365-367.]

5th CENTURY.

- "Aganis."** [Definition of parallel lines.] [Q1aα]
[Quoted by Simplicius, whose commentary on Euclid is preserved by
AN-NAIRIZI, ed. Besthorn-Heiberg (1893), p. 9.]
- Simplicius.** [Commentary on Euclid.] [Q1aα]
In the Commentary of AN-NAIRIZI, ed. Besthorn-Heiberg (1893), pp. 9-41,
119-133; ed. Curtze (1899), pp. 1-37, 65-73.

9th CENTURY.

- Thābit b. Qurra.** [Tract on the propositions and questions which arise when two
straight lines are cut by a third (or on the "proof" of Euclid's postulate).]
[Q1aα]
MS. Paris 2457, 39° (Woepcke, Paris, Mém. prés. div. sav. Ac. sc., 14
(1856), 666, 668.)

10th CENTURY.

- Yūhannā al-Qass.** [Tract on the "proof" of the case of two straight lines both meeting a third and making with it, on one side, two angles together less than two right angles.] [Q1aα]
[Mentioned in the Fihrist (*see* SUTER, 1892), p. 38.]

12th CENTURY.

- Athelhard of Bath.** [Translation of the Elements of Euclid from the Arabic into Latin.] [Q1aα]
MSS. exist in British Museum (Cod. Harleian, Nos. 5404 and 5266, Burney MSS. 275 [14th cent.]); Oxford (Trin. Coll., Cod. 47 and Ball. Coll., Cod. 257, both of 12th cent.); Nürnberg (Johannes Regiomontanus's copy); Erfurt; Wien, Nos. 2367 and 2465.

13th CENTURY.

- Naṣīraddīn.** [A treatise on the 5th postulate.] [Q1aα]
MS. Berlin 5942, Paris 2467, 6°.

1482.

- Euclid.** Preclarissimus liber elementorum Euclidis perspicacissimi: in artem Geometrie incipit quam foelicissime. [Q1aα]
[Without title-page.]
Venezia: Erhard Ratdolt. fol.
[Latin version from the Arabic by Johannes Campanus. The first printed edition of the Elements.]

1533.

- Euclid.** Εὐκλείδου στοιχείων βιβλ. ιε' ἐκ τῶν Θεώρων συνουσιῶν. Εἰς τοῦ αὐτοῦ τὸ πρῶτον, ἐξηγημάτων Πρόκλου βιβλ. δ'.
Adjecta praefatiuncula in qua de disciplinis Mathematicis nonnihil.
Basel: Joh. Herweg. fol. Ed. by Simon Grynaeus. pp. 268 of the Elements and 115 of the Commentary.
[1st ed. of the Greek text, but based on the worst MSS.]

1557.

- Peletier, J.** In Euclidis Elementa Geometrica Demonstrationum libri sex. [Q1aα]
Leiden. fol.
Secunda editio, auctior et emendatior: cui et textus Euclidis Graecus additus est. Lyon. 4to. 1610.

1560.

- Proclus.** Procli Diadochi Lycii philosophi platonici et mathematici probatissimi in primum Euclidis Elementorum librum commentariorum ad universam mathematicam disciplinam principium eruditionis tradentium libri IIII summa opera a Francisco Barocio patritio veneto expurgati Scholiis et Figuris aucti primum iam romanae linguae venustate donati et nunc recens editi. [Q1aα]
Padova. fol.

1569.

- Ramus. P.** Scholarum mathematicarum libri XXXI. [Q1aα]
Lib. V, p. 41; Lib. VII, p. 165.
Basel. 4to.

1570.

- Billingsley, H.** The Elements of Geometrie of the most auncient Philosopher Euclide of Megara. Faithfully (now first) translated into the Englishe tongue, by H. Billingsley, Citizen of London. Whereunto are annexed certaine

Scholies, Annotations, and Inventions of the best Mathematiciens, both of time past, and in this our age. With a very fruitful Praeface made by M. I. Dee, specifying the chiefe Mathematicall Sciēces, What they are, and whereunto commodious: where, also, are disclosed certaine new Secrets Mathematical and Mechanicall, untill these our days greatly missed. [Q1aα]

London: John Daye. fol.

(See HALSTED, 1879.)

1572.

Euclid. Euclidis elementorum libri XV. una cum Scholiis antiquis. A Federico Commandino Urbinatē nuper in latinum conversi, commentariisque quibusdam illustrati.

Pisaurum (= Pesaro): Camillum Francischinum.

1574.

Clavius, C. Euclidis elementorum libri XV. Accessit XVI. de solidorum regularium comparatione. Omnes perspicuis demonstrationibus, accuratisque scholiis illustrati. [Q1aα]

Roma. 8vo.

2nd ed. (Vol. I, pp. 144-161), 1589, Roma; 3rd ed., 1591, Frankfurt;

4th ed., 1603; 5th ed., 1607; 6th ed., 1612; 22 eds. up to 1738.

Opera, t. I., Mainz, 1591.

1587.

Patricio, F. Della nuova geometria.....libri XV.

[Q1aα]

Ferrara. 4to.

1594.

Nasiraddin. كتاب تحرير أصول لأوقليدس من تأليف خوجة نصيرالدين الطوسي
Euclidis Elementorum geometricorum libri tredecim. Ex traditione doctissimi Nasiridini Tusini nunc primum Arabicè impressi. [Q1aα]

Roma: In Typographia Medicea. fol.

[Some copies without the Latin title.]

Trans. Sanskrit, 1901: Latin (in part), 1693.

(See also SACCHERI, 1733.)

A shorter form printed at Constantinople, 1801, and in part at Calcutta, 1824.

MS. at Florence, Pal. 272 and 313.

Shorter form MSS.: Berlin, Munich, Oxford, British Museum (974, 1334³, 1335), Paris (2465, 2466), India Office, and Constantinople.

1603.

Cataldi, P. A. 1. Operetta delle linee rette equidistanti, et non equidistanti.

Bologna. 4to. pp. 36.

[Q1aα]

1a. Opusculum de lineis rectis aequidistantibus, et non aequidistantibus.

Bologna. 4to. pp. 36.

1604.

Cataldi, P. A. Aggiunta all' operetta delle linee rette equidistanti, et non equidistanti.

Bologna. 4to.

[Q1aα]

Kepler, J. Ad Vitellionem paralipomena, quibus astronomiae pars optica traditur; potissimum de artificiosa observatione et aestimatione diametrorum deliquiorumque solis et lunae. Cum exemplis insignium eclipsium, &c.

Frankfurt. 4to.

[Q1aα]

Opera omnia, ed. Frisch, Frankfurt and Erlangen, Stuttgart (printed), 1858-71 (Vol. II, pp. 185-188).

(Cf. also Newton, Principia, 1687, Book I, Sect. V, Schol. to Lemma XVIII.)

Oliver, T. De rectorum linearum parallelismo et concursu doctrina geometrica, qua demonstratio quintae petitionis Euclidis certissimis notissimisque principiis extracta continetur. [Q1aα]

In: De Sophismatum praestigiis cavendis admonitio.....Cambridge:
J. Legat. 4to. (pp. 5.)

1613.

Valerio, L. Trattato sulla quinta dimanda del primo d'Euclide. [Q1aα]
Circ. 1613 (S. & E.).

1615.

Cataldi, P. A. Euclidis Elementorum libri XV. per D. Heurion, et quintum et septimum postulatam e primo Euclidis demonstratione et breviter comprobata a Petro Antonio Cattaldo. [Q1aα]
Paris. 8vo.

1621.

Savile, H. Praelectiones tresdecim in principium Elementorum Euclidis habitae 1620. [Q1aα]
Oxford. 4to.

1639.

Desargues, G. Brouillon project d'une atteinte aux événemens des rencontres d'un cone avec un plan. [Q1aα]
Œuvres de Desargues. Paris, 1864, Vol. I, p. 104.

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Guldin, P. Centrobarica seu de centro gravitatis trium specierum quantitatis continuae. [Q1aα]
Lib. IV.
Wien. fol.

1642.

Gestrin, M. In geometriam Euclidis demonstrationum libri sex. [Q1aα]
Upsala. 4to. pp. 352.

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Tacquet, A. Elementa geometriae planae et solidae, quibus accedunt selecta ex Archimede theoremata. [Q1aα]
Antwerp. 4to.
Editio secunda correctior. Antwerp. 8vo. 1665. Ed. tertia.....
Ib. 1672. Also Amsterdam, 1701, 1725; Rome, 1745.

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Hobbes, T. Elementorum philosophiae sectio prima. (The first grounds of philosophy.) [Q1aα]
London.
The English Works of Thomas Hobbes, ed. by Sir William Molesworth.
Vol. I. London, 1839. 8vo. (Chap. IV, § 12, pp. 189-190.)

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Hobbes, T. Six lessons to the professors of the mathematics, one of geometry, the other of astronomy, in the chairs set up by the noble and learned Sir Henry Savile, in the university of Oxford. [Q1aα]
London.
The English Works of Thomas Hobbes, ed. by Sir William Molesworth.
Vol. VII. London, 1845. 8vo. (Lesson I: "Of the Principles of Geometry," pp. 205-206.)

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- Borelli, G. A.** *Euclides restitutus, sive prisca geometriae elementa, brevius et facilius contexta.* [Q1a α]
 Pisa. 4to.
 Trans. Italian by Domenico Magni, 1663 (*Heath*).

1667.

- [**Arnauld, A.**] *Nouveaux Eléments de Géométrie.* [Q1a α]
 Paris. 4to.
 2nd ed., 1683; den Haag, 8vo. 1690; Nouv. ed. La Haye, 12mo. 1711.

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- Guarini, G.** *Euclides adauctus et methodicus, mathematicaque universalis.* [Q1a α]
 Torino. fol.

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- Pardies, I. G.** *Éléments de Géométrie, où par une méthode courte et aisée on peut apprendre ce qu'il faut sçavoir d'Euclide, d'Archimède, d'Apollonius, et les plus belles inventions des anciens et des nouveaux Géomètres.* [Q1a α]
 Paris. 12mo.
 4 éd., Paris. 12mo. 1683, and La Haye, 1690; 5 éd., La Haye, 1705. 12mo; English translation by John Harris, London, 1701 12mo; 2nd ed., 1702. 8vo; 3rd ed., 1705; 6th ed., 1725: 8th ed., 1746.
 Also in: *Œuvres de Mathématiques; contenant les Éléments de Géométrie, &c.* La Haye. 12mo. 1691; (5 ed., 1705).

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- Leibniz, G. W.** [Letter to Huygens.] [B 12c]
 8 September, 1679. (Cf. HANKEL, 1867.)

- More, H.** *Enchiridion Metaphysicum: sive, de rebus incorporeis succincta et luculenta Dissertatio.* [Q2a]
Opera Omnia, tum quae Latine, tum quae Anglice scripta sunt; nunc vero Latinitate donata. Vol. II. London, 1679.
 Part I, Cap. 28, § 7.
 [This work has really nothing to do with a fourth dimension of space, though four dimensions are assigned to spirits, viz.—length, breadth, depth and “essential spissitude.” See ZIMMERMANN, 1881.]

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- Giordano da Bitonto, V.** *Euclide restituito overo gli antichi elementi geometrici restaurati, e facilitati.* Libri XV. [Q1a α]
 Roma. fol.

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- Giordano da Bitonto, V.** *Euclide restituito da V. G. da B.....* Libri XV., nei quali principalmente si dimostra la compositione delle proportioni secondo la definitione datane dal suo antico Autore. Seconda impressione con nuove Additioni.
 Roma. fol. (Vol. I of a course of mathematics, pp. 792.) [Q1a α]

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- Naṣīraddīn.** *Nasaraddini Demonstratio.* [Q1a α]
 (Delivered in a lecture by Wallis, 1651. Opera t. II. Oxford, 1693. fol. p. 669.)
 (See 1594.)

- Wallis, J. 1. De Postulato quinto; et definitione quinta Lib. 6 Euclidis; disceptatio geometrica. [Q1aα]
Opera t. II. Oxford. fol. pp. 665–673.
- 2. Demonstratio Postulati Quinti. [Q1aα]
(Delivered in a lecture, 1663. Opera t. II. pp. 674–678.)
Trans. German, 1895.

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- Chales, C. F. M. de. The Elements of Euclid, Explain'd in a New, but most Easie Method, Together with the Use of every Proposition through all parts of the mathematics. Written in French by that Excellent Mathematician F. C. F. M. de C. of the Society of Jesus. Now made English and a multitude of Errors corrected, which had escaped in the original. 3rd ed. Trans. by Wm. Halifax. [Q1aα]
Oxford. 8vo.
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Mathematische Schriften hrsgbn. von C. J. Gerhardt (1849–1863).
[Vols. I–IV, math. letters; V–VII, papers.]
V, 147.

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Oxford. fol.

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- Wolf, C. Die Anfangsgründe aller mathematischen Wissenschaften. Erster Theil. [Q1aα]
Halle. 8vo.

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- Leibniz, G. W. Essais de Théodicée sur la Bonté de Dieu, la Liberté de l'Homme, et l'Origine du Mal. [V1d]
Amsterdam. 8vo. 2nd ed. (§ 351.)
(Cf. KANT, 1746.)

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(Cf. Nasiraddin, 1594.)

- Wolff, C. Elementa Matheseos Universae. t. I. [Q1aα]
Halle. 4to. 1715 (*S. & E.*), 1730 (*J.*).

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Paris. 4to.

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- Saccheri, G. Euclides ab omni naevo vindicatus; sive conatus geometricus quo stabiliuntur prima ipsa geometriæ principia. [Q1aα, b, c (K)]
Milano. 4to. (Book I, pp. xiv + 101.)
Trans. English, see HALSTED, 1894¹; German, 1895; Italian, 1904.

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Leipzig. 4to.

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Göttingen. 8vo. 1739. Halle, 1756. (*S. & E.*)

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- Clairaut, A. C.** 1. *Éléments de Géométrie.* [Q1aα]
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1a. *Elements of Geometry*.....Trans. by J. Kaines. Kegan Paul
& Co.: London, pp. xxi + 118. 8vo. (1881.)

- La Caille, N. L. de.** *Leçons élémentaires de mathématiques.* [Q1aα]
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M. l'Abbé Maire; suivies de notes et additions par M. Lebey.
Paris, 1811. 8vo. (p. 241.)

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delen som innehåller de sex första böckerna. [Q1aα]
Upsala. 8vo.

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- Kant, I.** *Gedanken von der wahren Schätzung der lebendigen Kräfte und Beur-*
theilung der Beweise derer sich Herr von Leibnitz und andere Mechaniker
in dieser Streitsache bedienen haben, nebst einigen vorhergehenden Betracht-
ungen, welche die Kraft der Körper überhaupt betreffen. [Q2a, V1d]
Königsberg. 8vo. pp. 240 (pp. 9-15).
[Referred to by GERLACH, 1877.]
(Cf. LEIBNIZ, 1712.)

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Institutions de géométrie, enrichies de notes, critiques et philosophiques,
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- Segner, J. A.** *Deutliche und vollständige Vorlesungen über die Rechenkunst und*
Geometrie. [Q1aα]
Lemgo. 4to.
Simpson, T. *Elements of plane geometry.* To which are added, an Essay on the
maxima and minima of geometrical quantities, and a.....Treatise of regular
solids; also, the mensuration of.....superficies and solids, together with
the construction of a.....variety of geometrical problems. [Q1aα]
London. 8vo. 1747. 4th ed., 1780; 5th ed., 1800. Also 1821.

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et demonstrationem possibilitatis parallelarum publice eruditorum examini
subjiciunt Fredericus Gottlob Hanke et Benjamin Gottlob Binder. [Q1aα]
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Tomus I. [Q1aα]
Roma. 8vo. 1752 (*J.*), 1754 and 1759 (*S. & E.*).
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Societatis Jesu.
.....Editio prima Veneta.....ab erroribus expurgata.
Venezia,* 1757. 8vo. (p. 6.)

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Tübingen. 4to. [Q1aα]

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Tübingen. 4to. [Q1aα]

- Sauveur, J.** Géométrie élémentaire et pratique du feu M. Sauveur M. le Blond.
Paris. 4to. [Q1aα]

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- Simson, R.** 1. The Elements of Euclid, viz. The first six books together with the eleventh and twelfth. In this Edition Errors by which Theon, or others, have long ago vitiated these books are corrected and some of Euclid's Demonstrations are restored. [Q1aα]

Glasgow. 4to.

2nd ed., Glasgow, 1762. 8vo; 4th ed., containing Trigonometry, Edinburgh, 1772; 5th ed., 1775; 6th ed., 1781; 7th ed., 1787; 8th ed., 1781; —Glasgow, 1803.

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- 2. Euclidis Elementorum libri priores sex, item undecimus et duodecimus, ex versione Latina Federici Commandini; sublatis iis quibus olim Libri hi a Theone aliisve, Vitiati sunt; et quibusdam Euclidis demonstrationibus restitutis. [Q1aα]

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See EUCLID, 1572.

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Göttingen. 8vo.

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- Koenig, C. G.** Éléments de Géométrie, contenant les six premiers livres d'Euclide, mis dans un nouvel ordre et à la portée de la jeunesse. [Q1aα]
den Haag.

- Montucla, J. É.** Histoire des Mathématiques. t. I. [V2bγ]
Paris. 4to.

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- [**Alembert, J. d'.]** Mélanges de Littérature, d'Histoire et de Philosophie.

Nouvelle éd. (t. V, pp. 200–219). Amsterdam. 8vo. (S. & E.) [Q1aα, V2bγ]
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Torino, Misc. phil. math. Ac. Sc., 1, 113.

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(See GENOCCHI, 1869.)

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Jena. 4to. pp. 28. [Q1aα]

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Göttingen. 4to. pp. 30. [V2bγ, 1aα]

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- Reid, T.** *An inquiry into the human mind on the principles of common sense.*
Edinburgh. [Q1c, V1d]
The works of Thomas Reid. Preface, &c., by Sir W. Hamilton. Vol. I,
6th ed., Edinburgh, 1863.
(Chap. VI, On Seeing, § 9 Of the geometry of visibles.)
(See COCKLE, 1889, and cf. HENRICI, 1884.)

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- Bezout, É.** *Cours de mathématiques à l'usage du corps royal d'artillerie.* 4 vols.
Paris, 1770–1772. 8vo. [Q1aα]
Scherffer, K. *Institutionum geometricarum pars prior sive geometria elementaris.*
Wien. 4to. [Q1aα]

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Leipzig, Acta Soc. Hassiacae, 1771, p. 1.

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- Luino, F.** *Lezioni di matematica elementare.* [Q1aα]
Milano. 8vo.

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Œuvres complètes, III, 659.
[Gives relation between the distances of 5 points in Euclidean space, formulæ which formed the basis of de Tilly's researches. Cf. also Cayley, Math. Papers I, No. 1.]

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Genève. 4to. t. II, p. 19. [Q1aα]
Karsten, W. J. G. *Versuch einer völlig berichtigten Theorie der Parallelen.* [Q1aα]
Halle a. S. 4to. pp. 20.
Kesaer, F. X. von. *Abhandlung über die Lehre von den Parallellinien.* [Q1aα]
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Abhandlungen der Anfangsgründe der Mathematik zum Gebrauche der
k.k. Ingenieur-Academie. Wien, 2 parts, pp. 34.
- Schultz, J.** Vorläufige Anzeige des entdeckten Beweises für die Theorie der
Parallellinien. [Q1aα]
Königsberg. 8vo.
See 1784.
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Auctore J.M.P.C.P. [Q1aα]
Parma. 8vo.

1784.

- Schultz, J.** Entdeckte Theorie der Parallelen, nebst einer Untersuchung über den
Ursprung ihrer bisherigen Schwierigkeit. Mit zwo Kupfertafeln. [Q1aα]
Königsberg. 8vo. pp. 114.
2. Ausgabe, 1786.
(See EICHLER, 1786, and GENSICHEN, 1786.)
- Venturi, G.** Memoria intorno alle linee parallele. [Q1aα]
(In his text-book : Proposizione di geometria piana.)
Modena. 4to.

1785.

- Ludlam, W.** The Rudiments of Mathematics. [Q1aα]
Cambridge. (See p. 145.)
2nd ed, London, 1809. (p. 180.)

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Berlin. 8vo. pp. 16. [Q1aα]
(See ANDERS, 1796 ; NORDMANN, 1823.)
- Eichler, C.** De theoria parallelarum Schultziana, auctoritate amplissimi Philo-
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dente Theaeneto [=Gottlob] Rüffer. [Q1aα]
Leipzig. 4to. pp. 25.
(See SCHULTZ, 1784.)
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Widerlegung der Bendavid'schen Abhandlung über die Parallellinien. [Q1aα]
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(See SCHULTZ, 1784.)

Hindenb. K. F. Noch etwas über die Parallellinien.—System der Parallellinien. [Q1aα]

Leipziger Mag. r. ang. Math., 1786, 3. Stück, 359–404.

[On LAMBERT's paper, 1786.]

Hofmann. Berichtigung der ersten Gründe der Geometrie nebst dem Beweise, dass ein einzelnes Körpertheilchen einen Raum einnimmt. [Q1aα]

Mainz.

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Reprinted in Stäckel and Engel: *Theorie der Parallellinien* (1895), pp. 152–207.

(See HINDENBURG, 1786.)

Pfleiderer, C. F. von. Theses inaugurales. [Q1aα]

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(See 1784.)

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Opuscoli matematici. Bassano. 8vo.

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(See BUNIÁKOVSKIJ, 1851; SCHULTÉN, 1852¹.)

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mässig construirte Begriffe, von eingebildeten und unendlichkleinen Grössen
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die Begriffe der geraden Linie, der Ebene, des Winkels allgemein, der winkel-
losen Formen, und der Krümmen, der verschiedenen Arten der Gleichheit
u. dgl. nicht nur scharf zu bestimmen, sondern auch ihr Seyn im Raume zu
beweisen und da die Frage ob zwey von der dritten geschnittene Geraden, wenn
die Summe der inneren Winkel nicht $= 2R$, sich schneiden oder nicht? niemand
auf der Erde ohne ein Axiom (wie Euklid das XI.) aufzustellen, beantworten
wird; die davon unabhängige Geometrie abzusondern, und eine auf die Ja-
Antwort, andere auf das Nein so zu bauen, dass die Formeln der letzten auf
einen Winkel auch in der ersten gültig seyen. Nach einem lateinischen Werke
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* i.e. the Tentamen (1832) whose imprimatur is dated 12 Oct., 1829.
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mentaux de la géométrie élémentaire. [Q1a α]
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Stuttgart.
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seguita da una nota, su di una dimostrazione analitica del postulato 5 di
Euclide, fondandola sul principio di omogeneità; e sul modo convenevole di
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Napoli, Atti Acc. sc. Soc. Borbonica, 6, 1-15.
[Riccardi ascribes this anonymous demonstration to V. Flauti; Amodeo
(Palermo, Rend. Circ. mat., 10, 48) finds, from indications given in
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- Ueberweg, F.** Die Principien der Geometrie, wissenschaftlich dargestellt. [Q1a α]
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[Trans. of 1828.]

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[Lu le 7 Août, 1851.]
[Reply to BUNIAKOVSKIJ, 1851.]
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[Trans. of 1828.]

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 (See VINCENT, 1856.)

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 [The relevant passage, pp. 80-81, is given in Gauss' Werke, VIII, 267-268.]

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 [Vincent's note, which contains Thibaut's proof, gave rise to a discussion, in which Chasles, Poincot, Le Verrier, and Terquem took part.]

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$$\left(\frac{\pi}{n^2-n}\right)^{\frac{1}{2}(n-1)} \cdot \frac{\Gamma(n)}{\Gamma\left\{\frac{1}{2}(n+1)\right\}} \cdot \frac{1}{n^{\frac{1}{2}}}.$$

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[Expanded form of 1863.]
[On p. 76, note (*), he mentions that Lagrange, in his conversations with Biot, stated his belief that he could find a proof of the parallel postulate in the independence of the formulae of spherical trigonometry. DE MORGAN (1872) tells that Lagrange, towards the end of his life composed a paper on parallel lines. He began to read it in the Academy, but suddenly he checked himself with the remark, " Il faut que j'y songe encore," slipped the paper into his pocket and sat down.]

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$$\frac{d^2 f}{dx_1^2} + \frac{d^2 f}{dx_2^2} + \dots + \frac{d^2 f}{dx_n^2} = 0.$$

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Sharp, W. J. C. [The following are the abridged statements of Questions in Math. Quest. Educ. Times, London, **48**]:—

1. Q. 2109. (J. Wolstenholme, Solution by W. J. C. S.) $A_1, \dots, A_5$ are 5 fixed points in S_3 . $V_1, \dots$ are the volumes of the tetrahedra $A_2A_3A_4A_5, \dots$; $C_1, \dots, r_1, \dots$ the centres and radii of the circumscribed spheres. P is a variable point. Then $\Sigma 1/(C_1A_i^2 - r_i^2) = 0$ and $V_i(C_1A_i^2 - r_i^2) = \Sigma V_i \cdot PA_i^2$. (Extension to S_n . The result for $n = 2$ was given in the Math. Tripos, 1886.) 177-178. [K²1]

2. Q. 3228. (J. Wolstenholme, with generalisations by W. J. C. S.) Properties of a tetrahedron with concurrent altitudes. Opposite edges are at right angles and the sums of squares of opposite edges are equal. The common perpendiculars to opposite edges pass through the orthocentre. The tetrahedron is self-conjugate with regard to a certain sphere. A 12-points sphere passes through the mid points of the edges and the feet of the common perpendiculars. A second 12-points sphere passes through the centroids of the faces, the feet of the perpendiculars and points of trisection of the lines joining the vertices to the orthocentre. Other properties of these spheres. 168-173; cf. London, Proc. Math. Soc., **18**, 344, 357, 358. [K²1]

3. Q. 4208. (H. S. Monck, with generalisation by W. J. C. S.) Three lines AL, BM, CN are drawn from the vertices of a triangle ABC through a point O to the opposite sides; prove that $2 \triangle ABC : \triangle LMN = AO \cdot BO \cdot CO : LO \cdot MO \cdot NO$. 165; cf. L. P. M. S., **18**, 339. [K²1]

4. Q. 6386. (W. S. McKay and W. J. C. S.) Generalisation of question in **34**, 41. Conjugate points on two hyperspheres which cut orthogonally. 167. [K²8]

5. Q. 6392. (E. B. Elliott, with solution by W. J. C. S.) Relation between volume coordinates and distances referred to a tetrahedron. 176. [K²1]

6. Q. 7335. A tetrahedron and its circumscribed sphere. 165; cf. L. P. M. S., **18**, 346. [K²1]

7. Q. 7488. (Prof. Hudson, with solution by W. J. C. S.) Relation between the forces acting from O to the vertices of a simplicissimum with resultant passing through the in-centre. 164, 166. [K²1, R4e]

8. Q. 7533. (J. J. Walker, with solution by W. J. C. S.) The centroid of the faces of a simplicissimum is the centre of the hypersphere inscribed in the s , whose vertices are at the centroids of the faces; with application to Question 7488. 164, 166; cf. L. P. M. S., **18**, 357. [K²1, R2f, 4e]

9. Q. 7660. (R. Knowles, with generalisation by W. J. C. S.) Cf. Q. 7335. 165; cf. L. P. M. S., **18**, 346. [K²1]

10. Q. 7954. Relation between radii of in- and e-scribed spheres. 166; cf. L. P. M. S., **18**, 355. [K²1]

11. Q. 7980. If AA', BB' etc. be concurrent lines drawn from the vertices of any tetrahedron ABCD to meet the opposite faces in A', B', etc., show that

$$\Delta A'BC : \Delta A'DB = \Delta B'AC : \Delta B'DA,$$

$$\Delta A'BD : \Delta A'CD = \Delta D'BA : \Delta D'AC, \text{ etc.}$$

166; London, Proc. Math. Soc., **18**, 338. [K²1]

12. Q. 8019. Locus of centroid of n particles at the vertices of a simplex whose weights are connected by a homogeneous relation. 57-58.

[K²2, R2f]

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- 15. Q. 8216. (J. J. Sylvester, with solution by W. J. C. S.) Distance between two points in homogeneous coordinates. 164; L. P. M. S., 18, 343. [K²1, 2]
- 16. Q. 8242. (J. J. Sylvester, with solution by W. J. C. S.) Volume of a simplicissimum expressed as a determinant. 47, 53, 55; 48, 164; L. M. P. S., 18, 327. [K²1]
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- 18. Q. 8927. (S. Tebay and J. Beyens, with generalisation by W. J. C. S.) Expression for volume of a tetrahedron in terms of the areas of the faces. 166; 47, 110-111; L. P. M. S., 18, 331-332. [K²1]
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- 23. Q. 9170. (S. Roberts, with solution by W. J. C. S.) If the planes of the faces of a tetrahedron are cut by a sphere, and on the circular intercepts as diametral sections four spheres are constructed, the radical centre of these spheres is the isogonal conjugate, relative to the tetrahedron, of the centre of the first-named sphere. 178-182; L. P. M. S., 18, 325-359. (Solution also by J. Neuberg for S_3 .) [K²1]
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(Description of the models and apparatus exhibited at the meeting of the Deutsche Mathematiker-Vereinigung at Nürnberg, 1892.)

L. Brill exhibits the models in gypsum of constant positive and negative curvature (216), the sheet brass models (217), the wire and thread models of the four-dimensional figures (141, 143), and the cardboard models and lithographs (142). See SCHILLING, 1903.

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श्री : रेखागणितम् सम्राट्जगन्नाथविरचितं (प्रथम-
भागात्मकं षष्ठाध्यायपर्यन्तम्) स्वर्गवासिमहाशयध्रुवोपपदेन
हर्षदरायात्मजेन हरिलालेन संस्करणार्थमङ्गीकृतं त्रिवेद्युप-
पदधारिणा प्राणशंकरसूनुना कमलाशंकरेण संशोधितं
स्वनिर्मिताङ्ग्लभाषाभूमिकाटिप्पणीभ्यां च समुपेतम् । तच्च
मुम्बापुरीस्थराजकोयग्रन्थशालाधिकारिणा "निर्णयसागरा"
रथमुद्रणयन्त्रालये मुद्रयित्वा शाके १८२३ वत्सरे १८०१
रित्रस्ताब्दे प्राकाश्यं नीतम् । प्रथमा आवृत्तिः मूलं
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$$\int (\sum l x)^s (\sum l' x)^{s'} (\sum l'' x)^{s''} dx dy \dots = \pi^{\frac{1}{2}\nu} \frac{s! s'! s''!}{(\sigma - s)! (\sigma - s')! (\sigma - s'')!} \cdot$$

$$\frac{(\sum l' l'')^{\sigma - s} (\sum l'' l)^{\sigma - s'} (\sum l l')^{\sigma - s''}}{\Gamma(\sigma + 1 + \frac{1}{2}\nu)}$$
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- $$\frac{a_0 x^n}{n+2} + \frac{a_1 x^{n-1}}{n+1} + \dots + \frac{a_n}{2} = 0$$
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PART II.

THE SUBJECT INDEX.

PRINCIPAL HEADINGS OF CLASSIFICATION.

B.

- 1d. Determinants and Matrices of n dimensions.
12. Vectors and complex quantities.

C.

- 2h. Integration within a domain of n dimensions.
- 4d. Differential forms.

J.

4. Theory of groups.
- 5b. Sets of points.

K².

Elementary geometry of n dimensions.

1. GEOMETRY OF THE SIMPLEX.
2. Analytical geometry; coordinates.
3. Anharmonic ratio, &c.
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5. Cylinders and right cones.
6. HYPERSPHERES.
7. Spherical simplexes and polytopes.
8. Systems of hyperspheres.
9. Construction of hyperspheres.
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11. Various questions; constructions.
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L³.

Quadratic varieties V_n^2 .

1. General.
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3. Poles and polars.
4. Centres, diameters, &c.
5. Sections by linear spaces.
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14. Various theorems.

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20. Surface and volume.

21. Special properties.

M.

- M⁵. Algebraic curves in S_n .

1. Projective properties.

2. Geometry on the curve.

3. Metrical properties.

4. Curves from the point of view of deficiency.

5. Special curves.

- M⁶. Algebraic varieties of $n-1$ dimensions in S_n , of order higher than the second.

- M⁷. Algebraic varieties of $n-k-1$ dimensions in S_n ($0 < k < n-2$) of order higher than the second.

1. Projective properties.

2. Metrical properties.

3. Varieties of the third order.

4. Varieties of the fourth order.

5. Varieties of order higher than the fourth.

6. Ruled varieties.

7. Varieties from the point of view of birational transformation.

- M⁸. Transcendental curves and varieties in S_n .

N.

- N⁵. Extension to n dimensions of complexes and congruences.

- N⁶. Connexes.

- N⁷. Other analogous systems.

- N⁸. Non-linear systems of n dimensions; enumerative geometry.

O².

Infinitesimal and kinematic geometry of n dimensions.

1. Curves in S_n .
2. Varieties of $n-1$ dimensions in S_n .
3. Varieties of $n-k-1$ dimensions in S_n .
4. Kinematic geometry.

P².

Geometric transformations in S_n .

1. Homography, homology.
2. Correlations and transformations by reciprocal polars.
3. Isogonal transformations.
4. Birational transformations.
5. Representation of one variety upon another.
6. Various transformations.

Q¹.

Non-euclidean geometry.

- (K) Geometry and trigonometry; analytical geometry, &c.
- (L) Conics and quadrics.
- (M) Algebraic curves and surfaces.
- (N) Complexes and congruences.
- (O) Infinitesimal geometry.
- (P) Geometric transformations.
 - a. The foundations of geometry; systems of axioms, &c.
- a α . THEORY OF PARALLELS.
- a β . Curvature of space; differential basis for geometry.
- a γ . Finite distances, Continuous groups, Calculus of variations.

- b. Hyperbolic geometry.
- c. Elliptic and spherical geometry.
- d. Various geometries.
- e. Concrete representations of non-euclidean geometry.

Q².

Space of n dimensions.

- a. Generalities.
- b. Representations of space of higher dimensions.
- c. Applications of n dimensions.

Q³.

Analysis situs.

Q⁴.

Geometry of situation; configurations.

R.

Dynamics.

S.

Mechanics of fluids.

T.

Mathematical physics.

V.

- 1a. Bibliographies and text-books.
- 1d. Logical principles and philosophy of geometry.
- 2b. History.

X.

- 9. Models.
- 10a. Magic squares extended to n dimensions.

B1d. DETERMINANTS AND MATRICES OF n DIMENSIONS.

- 1880. Scott (1, 2).
- 1884. Frattini.
- 1887. Schendel.
- 1904. Calegari.
- 1910. v. Sterneek.

B12. COMPLEX QUANTITIES AND UNIVERSAL ALGEBRA, WITH REFERENCE TO n DIMENSIONS.

B12c. AUSDEHNUNGSLEHRE.

- 1679. Leibniz.
- 1844. Grassmann.
- 1867. Hankel.
- 1874. Grassmann.
- 1878. Clifford (1), Grassmann.
- 1879. Schlegel.
- 1882. Cox.
- 1884. Buchheim (2).
- 1885. Schendel.
- 1889. Ball, Caspary.
- 1892. Müller.
- 1893. Peddie.
- 1894. Hyde.
- 1897. Lasker.
- 1898. Müller, Whitehead (1).
- 1900. Joly.
- 1903. Alibrandi, Hinton.
- 1905. Rath.
- 1908. Schweitzer, Wilson (2).
- 1909. Müller.

B12d. QUATERNIONS.

- 1871. Tait.
- 1882. Cox.
- 1883. Stéphanos.
- 1884. Buchheim (2).
- 1893. Peddie.
- 1897. Philip (*see* Hathaway).
- 1898. Wijthoff (2).
- 1899. Kotelnikov.
- 1901. Stringham.
- 1902. Dixon, Hathaway, Thue.
- 1903. Dassen, Hudson, Joly.
- 1905. Genese, Philipps, Stringham.

B12e. BIQUATERNIONS.

- 1873. Clifford.
- 1884. Buchheim (1, 3).
- 1896. A. M'Aulay.
- 1898. A. M'Aulay, Wijthoff (1).
- 1899. Cazzaniga.
- 1901. Stringham.

B12f. HYPERCOMPLEX NUMBERS.

- 1881. Peirce.
- 1885. Simony.
- 1886. Gibbs.
- 1888. Chapman, Schur.
- 1889. Study (2).
- 1892. Segre (2).
- 1893. Scheffers (1, 2, 4).
- 1896. Study (1).
- 1898. Joly.
- 1902. Vahlen (1).
- 1904. Brunn.
- 1909. Maillet.

C2h. INTEGRATION WITHIN A DOMAIN OF n DIMENSIONS.

- 1868. Beltrami (3).
- 1886. Morera.
- 1887. Hoppe (2), Padova.
- 1890. Volterra (1, 2).
- 1894. Andrade.
- 1895. Dyck.
- 1896. Nanson (2).
- 1897. Ricci (2), Zindler.
- 1898. de Franchis.
- 1899. Sommerfeld.
- 1900. Baker.
- 1902. G. H. Hardy, Kowalewski (1).
- 1903. Cayley, Hardy, Heffter, Störmer (1, 2).
- 1904. Dini, Young (1).
- 1905. Brunn, Pierpont.
- 1906. Hahn.
- 1908. Goursat, Hurwitz, Richardson.
- 1909. Lerch.

C4d. DIFFERENTIAL FORMS.(Ref. Q1a β , O² 2.)

- 1868. Beltrami (3).
- 1869. Christoffel (1, 2), Lipschitz (1, 2).
- 1872. Lipschitz (2).
- 1880. Voss (1).
- 1884. Ricci.
- 1888. Bianchi (2).
- 1889. Ricci.
- 1899. Lovett (1).
- 1900. Beliankin, Lovett (2).
- 1902. Bianchi (1).
- 1905. Smith.

J4. Theory of Groups.**J4e. DISCONTINUOUS GROUPS IN RELATION TO n DIMENSIONS.** (For groups of the regular bodies see K²4c.)

- 1893. Bianchi (1, 2).
- 1901. Burnside (3).
- 1905. Fubini (1).
- 1907. Young.
- 1908. Barrau (1), Young.
- 1909. Bianchi, Young.

J4f. CONTINUOUS GROUPS. (Ref. Q1a γ .)

Varieties which admit a continuous group.

- 1896. Fano (2-5).
- 1897. Bianchi, Fano (2).
- 1898. Ricci (1, 2).
- 1899. Cotton (1, 2), Ricci.
- 1901. Amaldi.
- 1902. Fubini (1, 2).
- 1903. Fubini (2-4), Ricci (1).
- 1904. Rimini.
- 1905. Fubini (2).
- 1908. Medici (1).
- 1909. Fubini (1).

Continuous groups which leave a quadric invariant. (See J4f β .)

- 1889. Werner.
- 1899. Del Prete.
- 1904. Fubini (4).
- 1906. Kowalewski (2).

Groups of motions (α) in n dimensions (β) in non-euclidean space.

- α . 1872. Klein (1).
- 1884. Lie.
- 1888. Page.
- 1893. Killing (2).
- 1894. Page.
- 1896. Kantor (1).

- 1898. Kowalewski.
- 1899. Bemporad, Kowalewski (1), Lovett (1), Marotte, Medolaghi, Westfall.
- 1900. Engel (1, 2), Lovett (2).
- 1902. Kowalewski (2).
- 1903. Bianchi (1, 2).
- 1905. Cotton, Levi (1, 2), Wilson.
- 1907. König, Medici, Wilson.
- 1908. Kummer, Medici (2).
- 1910. Bieberbach.
- β . 1875. Clebsch.
- 1893. Killing (2).
- 1901. Bagnera.
- 1903. Campbell, Ricci (1).
- 1904. Fubini (5).
- 1905. Ricci.
- 1909. Brouwer (3).

J5b. THEORY OF SETS OF POINTS (Cantor's Mengenlehre). (For Continuity in geometry see Q1a; for Correspondence between manifolds of different dimensions see P²5.)General theory of n -dimensional continuous manifolds. (Ref. V1d.)

- 1877. Cantor.
- 1878. Netto.
- 1879. Cantor (1, 2).
- 1883. Cantor (1-5).
- 1885. Cantor.
- 1887. Cantor, Loria (1).
- 1896. Schoenflies.
- 1899. Jürgens.
- 1900. Schoenflies.
- 1904. Schoenflies.
- 1905. Huntingdon.
- 1906. Lüroth.
- 1909. Mahlo.
- 1910. Janiszewski.
- 1911. Hessenberg (see Aubach).

Notion of dimensions.

- 1888. Beckmann.
- 1910. Fréchet (1).

Analysis situs.

- 1901. de Séguier.
- 1903. Osgood.
- 1904. Ames.
- 1905. Brunn, Veblen.
- 1908. Tietze.

Integration. (Ref. C2h.)

- 1904. Young (1, 2).
- 1905. Pierpont.

Notion of length and area.

1902. Lebesgue.
1903. Lebesgue, Osgood.

Continuity. (*See* Q1a.)

1895. Killing.
1903. Jourdain.
1904. Pexider, Veblen (1).
1906. Schoenflies (1), Severini.
1907. Combebiac (1).

Miscellaneous.

1885. Bendixon, Phragmen.
1889. Vivanti.
1894. Maccaferri.
1905. Borel, Fréchet, Lindelöf, Mahlo, Riesz (1, 2), Young.
1906. Schoenflies (2).
1910. Fréchet (1, 2).

K². ELEMENTARY GEOMETRY OF n DIMENSIONS. (For non-euclidean geometry of n dimensions *see* also Q1; for treatises *see* V1a η .)

General.

1843. Cayley.
1858. Schläfli.
1877. d'Ovidio (1, 2), Rudel (1).
1879. Hoppe (1).
1881. Veronese (3).
1885. Cassani (1, 2), Simony.
1886. Bertini (2).
1887. Cassani.
1889. Cole.
1891. Dixon.
1893. Del Pezzo (1).
1894. Brückner, Cassani.
1895. Aschieri, La Rive (1, 2), Lasker (1).
1898. Barbarin (1), Whitehead (1).
1899. Griend.
1901. Gravé, Schläfli, Stringham.
1902. Schoute (1).
1905. Hudson.
1907. Cutroni, Fick.
1910. Manning, Weitzenböck (2).

Angles between hyperplanes.

1872. Jordan.
1877. d'Ovidio (1), Rudel (2).
1882. Hoppe (3).
1885. Cassani (2-4), Castelnovo.
1895. Cassani.

1897. van Oss, Schoute (1).
1899. Berry.
1902. Keyser, Schoute (2).
1904. Schoute (4).
1910. Schoute (1).

Minimum distance between hyperplanes.

1902. Piccioli (2).

Relation between distances of given points.

1898. Lovett (2).
1899. Fontené (2), Klug.
1908. Mansion (2).

Point at minimum distance from given points.

1894. Schlegel (2).
1899. Loria (2).

Theorem of Pythagoras.

1882. Study.
1896. Schlegel.
1899. Klug.

Symmetry.

1827. Moebius.
1877. Rudel (3).
1890. Hoppe (1).
1891. Schoute (2).
1902. Piccioli (1).
1904. Brouwer (2).
1905. Lechalas.
1906. Butin.
1907. Hjelmslev (1).

K²1. Geometry of the Simplex.

General.

1858. Schläfli.
1887. Sharp.
1901. Schläfli.
1905. Piccioli.

Volume.

1866. Clifford.
1880. Scott (1).
1883. Hoppe (4).
1885. Sylvester.
1886. Cesàro, Lipschitz (2).
1888. Loria (2), Sharp (1, 16, 18).
1894. Liers.
1899. Giacomini (1), Lovett (6).

Centroid.

1863. Sylvester.
1883. Mehmke.
1888. Sharp (8).

Simplex with concurrent altitudes.

- 1883. Mehmke.
- 1888. Sharp (2, 22).
- 1890. Hoppe (2).
- 1908. Schuh (2).

Systems of two simplexes.

- 1905. Berzolari.
- 1906. Berzolari (1).

Simplexes, homothetic and in homology. (*Ref. P²1.*)

- 1866. Schläfli (2).
- 1886. Hess, Klug.
- 1904. Berzolari, Lasker.
- 1905. Natucci (1).

SIMPLEXES AND HYPERSPHERES.

Circumscribed hypersphere.

- 1881. Kretkowski.
- 1883. Mehmke.
- 1888. Sharp (6, 7, 9, 14, 19).
- 1890. Sharp.

Inscribed hypersphere.

- 1866. Clifford.
- 1888. Sharp (10).

Other hyperspheres connected with a simplex.

- 1888. Sharp (2).

Various theorems relating to simplexes and hyperspheres.

- 1887. Sharp.
- 1888. Sharp (1, 23).
- 1898. Kühne.
- 1901. Curjel, Neuberg and Schoute.
- 1903. Haskell, Meyer.
- 1904. Gordon and Nesbitt.

Various questions on the simplex. (*Ref. L³3b, 14, 17d.*)

- 1887. Hoppe (1, 2).
- 1888. Sharp (1-3, 5-13, 15, 16, 18, 19, 22, 23).
- 1907. W. F. Meyer (1).
- 1910. Piccioli.

K²2. ANALYTICAL GEOMETRY ; COORDINATES.

Barycentric coordinates.

- 1827. Moebius.
- 1863. Sylvester.
- 1888. Cesàro (4), Sharp (12).

Elliptic coordinates.

- 1879. Craig (2).
- 1887. Klein.

Line coordinates, &c.

- 1886. Brunel.
- 1898. W. H. Young.
- 1899. W. H. Young (1-3).
- 1902. Keyser.
- 1906. Coble.

Plücker's coordinates.

- 1906. Autonne.

Homogeneous coordinates.

- 1888. Sharp (14, 15).
- 1893. Killing (2).
- 1895. Kohn (2, 3).
- 1898. Giudice.

Projective coordinates.

- 1903. Morley.

Polyspherical coordinates.

- 1893. Klein (1).
- 1909. van Oss.

Polar coordinates.

- 1886. Schlegel (4).

K²3. ANHARMONIC RATIO ; &c. (*Ref. P²1.*)

- 1881. Veronese (3).
- 1882. Schlegel.
- 1884. Schur.
- 1885. Loria.
- 1886. Cassani (1).
- 1890. Stahl.
- 1892. Kühne, de Paolis.
- 1893. Busche.
- 1899. Richmond.
- 1900. Richmond (1).
- 1901. Kantor (2), Lazzeri.
- 1903. Kijlstra, Lorenzola.
- 1904. Carver.
- 1906. Lazzeri.

K²4. Polytopes. (For Models see X⁹.)

- 1858. Schläfli.
- 1894. Brückner.
- 1901. Schläfli.
- 1905. Schoute (4).

K²4a. *n*-DIMENSIONAL ANGLES.

- 1881. Hoppe (1, 3, 4).
- 1882. Hoppe (1).
- 1883. Hoppe (1-3, 5).
- 1885. Hoppe.
- 1898. Heyl.
- 1909. Schoute.

K²4b. GENERALITIES ON POLYTOPES.

- 1858. Schläfli.
- 1881. Durège, Hoppe (2).
- 1882. Schlegel.
- 1884. Biermann.
- 1886. Lipschitz (1).
- 1888. Cesàro (1).
- 1901. Schläfli.
- 1902. Schubert.
- 1904. Schoute (7).
- 1905. Schoute (4).

Euler's formula. (*Ref. K²10.*)

- 1880. Stringham (3).
- 1881. Forchhammer.
- 1882. Reich.
- 1893. Poincaré.
- 1905. Dehn (2), Poincaré (4).
- 1908. Schuh (1).

K²4c. REGULAR POLYTOPES.

- 1858. Schläfli.
- 1880. Emsmann, Stringham (1, 2).
- 1881. Forchhammer, Hoppe (2).
- 1882. Hoppe (1, 2), Rudel.
- 1883. Schlegel (1).
- 1884. Biermann, Puchta (1, 2).
- 1885. Hess.
- 1886. Hess, Schlegel (2, 3).
- 1887. Rudel.
- 1888. Cesàro (1).
- 1889. Goursat.
- 1891. Schoute (1).
- 1892. de Galdeano.
- 1898. Heyl.
- 1899. Curjel, Gosset, Hess.
- 1901. Schläfli.
- 1903. Boucher (2), Schoute (5).
- 1905. Schoute (4).
- 1906. Lepiney.
- 1908. Andreini.
- 1909. Schoute.
- 1910. Stott (1).

Projections and sections.

- 1891. Schlegel (3).
- 1892. Hall.
- 1893. Hall, Schlegel, Schoute (1, 2).
- 1899. Schoute (3).
- 1900. van Oss, Stott.
- 1904. Bryan, Schoute (3).
- 1905. Schoute (4).
- 1906. Barrau (1).
- 1907. Schoute (1), Stott (2).
- 1908. Schoute (1-3).

Groups of the regular polytopes.

- 1884. Puchta (1).
- 1887. Biermann.
- 1889. Goursat.
- 1894. van Oss, Schoute.
- 1896. Maschke (1, 2).
- 1899. Le Vasseur (2).
- 1900. van Oss, Wiman.

K²4ca. SEMI-REGULAR POLYTOPES.

- 1888. Cesàro (1).
- 1899. Gosset.
- 1903. Schoute (1).
- 1904. Hinton (2).
- 1907. Stott and Schoute (1).
- 1908. Andreini.
- 1910. Stott (1, 2).

Crystal forms.

- 1895. Schoute (2).
- 1896. Schoute (2).
- 1905. Schoute (4).

K²4d. AREAS AND VOLUMES OF POLYTOPES; CENTRES OF GRAVITY.

- 1888. Kummell.
- 1896. Schoute (1).
- 1904. Schoute (1).

K²4e. SIMILITUDE AND HOMOTHETY. (*Ref. P²1.*)**K²4ea. Homology.**(For simplexes *see* **K²1.**)

- 1888. Rahnsen.

K²4f. SPECIAL POLYTOPES.

- 1910. Schoute (2).

Parallelotopes.

- 1887. Schlegel.
- 1896. Höppner.
- 1903. Schoute (2, 4).
- 1907. Schoute (2).
- 1908. Voronoj.

Star polytopes.

- 1858. Schläfli.
- 1885. Hess.
- 1901. Schläfli.
- 1905. Schoute (4).
- 1906. Mulder.

K²4g. DIVISION OF SPACE BY POLYTOPES. (For division of the non-euclidean plane and space *see* **Q1 (K²9b, 14g.)**)

- 1890. Eberhard.
- 1891. Schlegel (1).

1895. Schoute (1).
 1899. Curjel, Gosset.
 1908. Andreini, Schoute (1, 2),
 Voronoj.
 1909. Jansen.
 1910. Stott (1).

K²5. a. CYLINDERS. b. RIGHT CONES.

K²6. Hyperspheres.

Volume and surface.

1866. Clifford.
 1882. Routh.
 1886. Cesàro.
 1897. Heyl (1).
 1899. Liebmann (1).

Turning a spherical shell inside out.

1878. Monro (1), Newcomb (1).

Analogous deformations.

1899. Mannoury (1).

Various problems on hyperspheres.

(See also **K²1**.)

1901. Jung.
 1903. Cayley, Hardy.
 1907. Bateman and Sommer-
 ville.
 1908. Schoute (4).
 1910. Bateman.

K²7. SPHERICAL SIMPLEXES AND POLYTOPES.

1858. Schläfli.
 1885. Hess.
 1901. Schläfli.
 1905. Poincaré (4).
 1906. Piccioli.
 1909. Sforza (3).

K²8. SYSTEMS OF HYPER- SPHERES.

1888. Sharp (4, 21).
 1885. Cassani (2).
 1896. Schlumberger.
 1905. Schoute (2).
 1907. Bateman and Sommer-
 ville.
 1909. van Oss.

Linear systems.

1888. Del Re (2).
 1896. Schlumberger.
 1899. Giacomini (2).

K²9. CONSTRUCTION OF HYPER- SPHERES.

1885. Cassani (2).

K²10. POLYGONOMETRY.

Extension of theorem for angle-sum.
 (Ref. **K²4b**.)

1905. Dehn (2), Poincaré (4).

Extension of Napier's rule.

1907. Wijthoff.

K²11. VARIOUS QUESTIONS ; CONSTRUCTIONS.

1901. Pearson.
 1907. Nanson and Sommerville.

K²12. DESCRIPTIVE GEOMETRY.

1882. Veronese.
 1884. Cassani.
 1902. Loria (2).
 1904. Marletta (2), Mehmke.
 1905. Nicoli.
 1906. Perazzo.

K²13. PERSPECTIVE.

1882. Fiedler.
 1885. Cassani (2).
 1886. Klug.
 1894. Hoppe.
 1903. van Uven.
 1905. de Vries (1).
 1906. Majcen.
 1909. Kruppa.

Stereoscopic projection.

1901. Carbone.
 1904. Bryan.

L³. QUADRATIC VARIETIES V_n^2 .

1881. Veronese (3).
 1884. Segre (5).
 1898. Whitehead (1).
 1907. Bertini.

L³1. GENERALITIES.

a. DEFINITIONS, EQUATIONS ; CLASSI- FICATION.

1894. Hensel.
 1899. Wijthoff.
 1906. Sommerville (1).

b. MODES OF GENERATION.

1899. da Porto.

L³2. QUADRATIC CONES AND CYLINDERS.

1884. Segre (4).

L³3. POLES AND POLARS.

1890. Burali-Forti.
 1900. Richmond (3).
 1904. Morley and Nesbitt,
 Nanson.

a. GENERAL THEORY.

b. CONJUGATE AND SELF-CONJUGATE SIMPLEXES.

1866. Schläfli (2).
 1884. Rosanes.
 1905. Berzolari, Brusotti.
 1906. Guareschi.

d. POLAR SYSTEMS.

1904. Carver.

L³4. CENTRES, DIAMETERS, DIAMETRAL AND PRINCIPAL PLANES AND SPACES; ASYMPTOTIC CONES.L³5. SECTIONS BY LINEAR SPACES.

1893. Nicoli.
 1899. Nanson.

L³6. TANGENT SPACES AND CIRCUMSCRIBED CONES.

1906. Bianca.
 1908. Richmond.

L³7. LINEAR SPACES LYING ON A V_n^2 .

1873. Cayley (2).
 1884. Segre (5).
 1895. Bertini.
 1900. Richmond (2).
 1905. Fano.
 1909. Darboux (1).

L³8. NORMALS.

1884. Müller.
 1908. Woude.

L³9. FOCALS.

1900. Concina, Sommer (2).
 1903. Toxopeus.

L³10. CONFOCAL V_n^2 .

1900. W. F. Meyer, Sommer (2).
 1901. Dixon.
 1903. Toxopeus.
 1907. W. F. Meyer (2).

L³11. CURVATURE.

1884. Müller.
 1903. Toxopeus.

L³12. GEODESICS.

1898. Rudio.
 1900. Sommer (1).
 1903. Toxopeus.

L³13. VARIETIES LYING ON A V_n^2 .

1872. Klein (4).
 1906. Guichard.

L³14. VARIOUS THEOREMS RELATING TO A V_n^2 .

1868. Geiser.
 1896. Berzolari.
 1897. Snyder.

L³14a. GENERALISATION OF PASCAL'S THEOREM.

1901. Meyer.
 1903. Kijlstra.
 1909. Carver (1).

L³15. CONSTRUCTION OF A V_n^2 DETERMINED BY $\frac{1}{2}n(n+3)$ CONDITIONS.L³16. GEOMETRICAL LOCI AND ENVELOPES DEDUCED FROM A V_n^2 .

1884. Segre (1), Veronese (3).
 1886. Klein.
 1899. Schoute (1).

L³17. SYSTEMS OF TWO V_n^2 ; SHEAFs.

1884. Segre (4, 5).
 1886. Bertini (3).
 1898. Rosati.
 1899. Rosati.
 1907. Brusotti, Predella.
 1909. Rohn (2).

L³17a. VARIETY COMMON TO TWO QUADRICS. (See M⁷4.)L³17c. POLAR RECIPROCAL OF ONE QUADRIC WITH RESPECT TO ANOTHER.

1885. Del Pezzo (1).

L³17d. COMMON SELF-CONJUGATE SIMPLEX.

1896. Nanson (1).

L³18. SYSTEMS OF THREE V_n^2 ; NETS.

1901. Schoute (4).

**L³19. LINEAR SYSTEMS OF V_n^2
WITH MORE THAN TWO
PARAMETERS.**

- 1895. Del Pezzo.
- 1899. Schoute (1).
- 1900. Schoute (5).
- 1902. de Zoukis.
- 1906. Bricard (3).
- 1908. Brusotti.
- 1909. Carver (1, 2), Rohn (1).

L³20. SURFACES AND VOLUMES.
1909. Cisotti.

**L³21. SPECIAL PROPERTIES OF
CERTAIN V_n^2 .**

- 1906. Barrau and Schoute (2).

**M. ALGEBRAIC CURVES AND
VARIETIES IN S_n .**

M⁵. ALGEBRAIC CURVES IN S_n .

M⁵1. PROJECTIVE PROPERTIES.

- 1875. Halphen (1).
- 1878. Clifford (2).
- 1881. Veronese (3).
- 1884. Lindemann.
- 1887. Segre (1).

Application of automorphic func-
tions.

- 1903. Richmond (3).
- 1909. Richmond (1).

M⁵1a. TANGENTS, &C.

- 1898. White.
- 1910. Hatzidakis, Meyer.

Singularities.

- 1886. Fine.
- 1887. Fine.
- 1893. Del Pezzo (2, 3), Meyer
(1-3).
- 1902. Severi (3).
- 1906. Berzolari (2, 3).

Maximum deficiency.

- 1894. Fano.
- 1898. Amodeo.
- 1901. Kantor (4).

Plücker's formulæ.

- 1881. Veronese (1).
- 1889. Castelnuovo (1).
- 1903. Richmond (3), Schoute
(3).
- 1904. Schoute (2).
- 1905. Lasker.
- 1909. Richmond (1).

M⁵1b. MULTISECANTS. (Ref. N⁵2a.)

- 1902. Severi (1).
- 1906. Schoute (3).

M⁵1f. LINEAR SYSTEMS.

- 1887. Segre (3).
- 1892. Segre (1).
- 1901. Schoute (1).

M⁵2. GEOMETRY ON THE CURVE.

- 1887. Kötter, Le Paige.
- 1889. Castelnuovo (5).
- 1891. F. Deruyts.
- 1893. Berzolari.
- 1894. Segre.
- 1896. Segre (2).
- 1897. Waelsch.
- 1898. Amodeo, F. Deruyts (1,
2).
- 1899. Morale (3).
- 1900. Scorza (2), Severi (1).
- 1902. Thompson.
- 1908. Bertini and Severi.
- 1909. Bertini (1).
- 1910. Bertini.

Correspondence between two curves.

- 1878. Clifford (2).
- 1886. Segre (2).
- 1889. Castelnuovo (1).
- 1890. Bertini.
- 1891. Amodeo (2).
- 1897. Kohn.
- 1900. Scorza (1).
- 1906. Marletta (1).

Groups of points on a curve.

- 1878. Clifford (2).
- 1886. Castelnuovo, Segre (4).
- 1887. Deruyts (1, 2).
- 1888. Castelnuovo (2), Stahl.
- 1889. Castelnuovo (2, 4).
- 1890. Klein (3), Schoenflies.
- 1891. Waelsch, White.
- 1893. Castelnuovo.
- 1898. Hardcastle, Palatini (2).
- 1899. Segre.

Normal curves. (For rational normal
curves see M⁵4a.)

- 1886. Bordiga (2).
- 1888. Segre (3).
- 1889. Castelnuovo (5), Deruyts.
- 1891. Amodeo (2).
- 1892. Klein (3).
- 1895. Wiman (1, 2).
- 1897. Kohn.
- 1899. Schoute (2).
- 1902. Kowalewski (2).

M⁵3. METRICAL PROPERTIES.

1880. Hoppe (1).
1910. Rath.

M⁵3d. NORMALS, &C.

1900. Schoute (4).
1903. Mehmke (2).

M⁵4. CURVES FROM THE POINT OF VIEW OF DEFICIENCY.

1881. Veronese (3).
1894. Fano.

M⁵4a. RATIONAL (UNICURSAL) CURVES.

1878. Clifford (2).
1882. Meyer (1-5).
1884. Meyer.
1886. Brambilla.
1887. Zecca.
1888. Loria (3).
1893. Berzolari.
1895. Fano (2).
1902. Thompson.
1905. Marletta (1).
1906. Marletta (1), Berzolari (2, 3).
1907. de Boer.
1908. Marletta (1).

Rational Normal curves (i.e. curves of degree n in S_n).

1878. Clifford (2).
1886. Cassani (2).
1888. Loria (4).
1895. Lasker (2).
1900. Schoute (3, 4).
1901. Schoute (1).
1903. Berzolari (1).
1905. Marletta (1).
1907. de Boer, Young.
1908. Young.
1909. Young.

$n = 4$.

1886. Bordiga (3).
1887. Aschieri.
1902. Marletta (2).
1904. Brusotti, Schönfeld.

M⁵4b. BICURSAL (ELLIPTIC) CURVES.

1878. Clifford (2).
1880. Bianchi, Klein (2).
1884. Klein.
1885. Klein, Meyer.
1886. Segre (2, 4).
1888. Castelnuovo (2).
1890. Klein (2).
1891. Amodeo (2).
1902. Rosati.
1908. Marletta (2).

M⁵4c. CURVES OF DEFICIENCY p .

1878. Clifford (2).
1888. Segre (3).
1892. Del Pezzo, Hurwitz, Klein (3).
1895. Wiman (1, 2).

M⁵5. SPECIAL CURVES AND FAMILIES OF SPECIAL CURVES; CLASSIFICATION.

1906. Hatzidakis.
1908. Conner.

M⁶. ALGEBRAIC VARIETIES OF $n-1$ DIMENSIONS IN S_n OF ORDER HIGHER THAN THE SECOND.**M⁶1. PROJECTIVE PROPERTIES.**

1875. Halphen (2).
1885. Moore.
1886. Bordiga (5).
1887. Segre (2).
1896. Segre (2).
1905. Giambelli (1).
1906. Giambelli (1).
1907. Bertini, Godeaux (1), Tanturri.
1909. Bertini (2), Coble.

M⁶1a. INTERSECTION OF TWO OR MORE VARIETIES.

1875. Halphen (2).
1888. Pieri.
1899. Levi.
1903. Severi (1, 2).
1905. Macaulay.
1906. Herglotz.
1909. Palatini (1).

M⁶1a β . Varieties passing through the intersection of given varieties.

1897. Delassus.

M⁶1b. MULTIPLE POINTS.

1896. Segre (1).
1905. Chizzoni (1).

Deficiency.

1869. Noether (1, 2).
1908. Fano (1).

Tangent planes.

1888. Sharp (17).

M⁶1c. POLES AND POLARS.

1886. Rodenberg.
1887. Brambilla.
1888. Sharp (20).

Systems of varieties with the same first polars.

1898. Bertini.

Hessian, etc.

1893. Ascione (2).

1895. Segre.

1900. Perazzo.

M⁶1d. CURVES, &C., LYING ON A VARIETY.

1893. Enriques (4).

1894. Enriques (2, 4).

1895. Enriques, Fano (3).

1902. Amaldi (1), Enriques (2).

1904. Fano (3, 4).

1905. Castelnuovo, Chizzoni (2)

1906. Bonnesen, Severi (3).

1907. Rosati.

1909. Severi.

M⁶1f. LINEAR SYSTEMS.

1882. Bertini.

1893. Enriques (5).

1895. Enriques.

1900. Palatini (1).

1901. Bertini.

1905. Lorenzola, Veneroni.

1907. Schuh (1).

1909. Bottasso.

M⁶2. METRICAL PROPERTIES.

M⁶2e. CENTRES OF MEAN DISTANCES.

1906. Laurent (1).

M⁶2g. FOCALS.

1898. Schoute (2).

M⁶2h. NORMALS.

1891. Pieri (2).

1899. Pellet (1).

1909. Rosati.

M⁶3. VARIETIES OF THE THIRD ORDER.

1886. Voss.

1887. Castelnuovo, Segre (7).

1888. Castelnuovo (1), Segre (4).

1893. Enriques (1).

1894. Enriques (3).

1896. Ascione.

1900. Perazzo.

1901. Perazzo.

1902. Dragoni.

1903. Richmond (1).

1904. Baker, Fano (1-4).

1905. Veneroni.

1909. Richmond (2), Snyder (1, 2).

M⁶4. VARIETIES OF THE FOURTH ORDER.

1895. Caldarera.

1897. Bordiga (1).

1902. Marletta (1).

1905. Amico.

Extension of Steiner's surface.

1897. Brambilla (1, 2).

1898. Brambilla.

1899. Brambilla (1, 2).

1900. Rosati.

1907. Tanturri.

1908. Schuh (1).

Extension of cyclides.

1896. Schoute (3).

1900. Snyder.

1907. Sommerville (2).

Extension of desmic tetrahedra.

1907. Barrau (1).

M⁶5. VARIETIES OF ORDER HIGHER THAN THE FOURTH.

1887. Bordiga.

1896. Cannizzo.

Extension of Kummer's surface.

1890. Wirtinger.

1907. Schuh (2).

1908. Schuh (1).

Fresnel's wave surface.

1895. Vahlen.

1897. Schoute (2).

Varieties of order $n-1$ in S_n .

1885. Del Pezzo (2).

1898. Palatini (1).

M⁶6. RULED VARIETIES.

1885. Del Pezzo (2).

1886. Segre (4).

1887. Segre (1, 4).

1893. Pincherle.

1895. Caldarera.

1897. Bordiga (1).

1898. Palatini (1).

1899. Morale (1, 2).

1901. Bellatella, Moreno, Pagliano.

1905. Chizzoni (1).

1908. Pagliano.

M⁷. VARIETIES FROM THE POINT OF VIEW OF REPRESENTATION AND BIRATIONAL TRANSFORMATION.

M^{7a}. RATIONAL VARIETIES.

M^{7c}. VARIETIES WHOSE PLANE SECTIONS HAVE A GIVEN DEFICIENCY.

- 1887. Del Pezzo (1).
- 1888. Moore.
- 1890. Castelnuovo.
- 1893. Enriques (5).
- 1894. Enriques (3).
- 1895. Enriques.
- 1901. Enriques (1), Kantor (1).
- 1908. Scorza (3).
- 1909. Scorza (3).

M^{7d}. HYPERELLIPTIC VARIETIES.

- 1906. Hutchinson.
- 1907. Enriques and Severi (1).
- 1909. Severi.

M^{7f}. BIRATIONAL TRANSFORMATIONS.

- 1900. Palatini (1).
- 1902. Enriques (2).
- 1906. Pannelli (1, 2).

M⁷. ALGEBRAIC VARIETIES OF $n-k-1$ DIMENSIONS IN S_n ($0 < k < n-2$) OF ORDER HIGHER THAN THE SECOND. (α prefixed signifies surfaces ($k=n-3$)).

M⁷¹. PROJECTIVE PROPERTIES.

- 1875. Halphen (1).
- 1886. α Del Pezzo (2).
- 1887. α Del Pezzo (1-3).
- 1891. Segre (2).
- 1896. α Autonne.
- 1897. Autonne (1), Pieri (2).
- 1906. α Palatini.
- 1907. Bertini, Giambelli.
- 1908. α E. E. Levi, Pannelli, Scorza (1, 3).
- 1909. Brusotti, Scorza (2).

M^{71a}. VARIETY AS COMPLETE INTERSECTION OF OTHERS.

- 1903. Severi (2).
- 1909. Fano, Pannelli.

M^{71b}. MULTIPLE POINTS.

- 1888. α Del Pezzo.
- 1901. α Severi.

Tangent and osculating planes, &c.

- 1886. α Del Pezzo (1).
- 1908. Scorza (1, α 2).
- 1909. Scorza (1).

M^{71d}. GEOMETRY ON A VARIETY.

- 1901. α Castelnuovo and Enriques.
- 1907. Severi.

M⁷². METRICAL PROPERTIES.

- 1897. α Kommerell.
- 1908. α E. E. Levi.

M⁷³. VARIETIES OF THE THIRD ORDER.

M⁷⁴. VARIETIES OF THE FOURTH ORDER.

- 1899. Chisholm Young, Rosati.

Surface of Veronese (α).

- 1868. Cayley.
- 1884. Veronese (1).
- 1885. Segre (1).
- 1900. Rosati.
- 1901. Severi.
- 1906. Palatini.

M⁷⁵. VARIETIES OF ORDER HIGHER THAN THE FOURTH.

- 1886. α Bordiga (6, 7).
- 1888. α Bordiga (1).
- 1905. α Schoute (3).
- 1907. Godeaux (2).
- 1910. α Fano.

M⁷⁶. RULED VARIETIES.

- 1884. α Segre (3).
- 1886. Bordiga (4), Segre (3, 4).
- 1887. Segre (5, 6).

M⁷⁷. VARIETIES FROM THE POINT OF VIEW OF DEFICIENCY.

M^{77a}. UNIORSAL VARIETIES.

- 1895. Autonne (α 1, 2).
- 1899. Autonne.

M^{77d}. HYPERELLIPTIC VARIETIES.

- 1910. α Chillemi.

M⁷⁸. TRANSCENDENTAL CURVES AND VARIETIES IN S_n .

- 1902. Kwietniewski.

Cylindrical helix.

- 1890. Pirondini.
- 1899. Piccioli.

**N. EXTENSION TO n DIMENSIONS
OF COMPLEXES, CONGRU-
ENCES, CONNEXES, &c.**

**N⁵. COMPLEXES AND CONGRU-
ENCES.**

N⁵1. COMPLEXES, &c., OF LINES.

- 1886. Bordiga (2).
- 1887. Castelnuevo.
- 1888. Bordiga (2), Castel-
nuovo (1), Schafstein,
Segre (2).
- 1889. Landsberg.
- 1890. Bordiga.
- 1891. Castelnuevo.
- 1894. Bordiga.
- 1896. Kantor (2), Ricci.
- 1897. Ascione (1, 2), Kantor (2).
- 1898. Bordiga, Levi, W. H.
Young.
- 1899. W. H. Young (1).
- 1900. Engel (2), Palatini (2),
v. Weber (1, 3).
- 1901. Carrone, Palatini (1), v.
Weber.
- 1902. Kantor (1), Palatini,
Pieri.
- 1903. Kantor (3), Palatini (1).
- 1904. Eiesland.
- 1905. Eiesland.
- 1907. Segre (1).
- 1908. Scorza (3), Weitzenböck.
- 1909. Marletta, Müller.
- 1910. Weitzenböck (1, 2).

Complexes and congruences of planes.

- 1903. Keyser.

Réseaux and Congruences.

- 1897. Guichard (1-8).
- 1898. Guichard (1-4).
- 1899. Guichard (1-6).
- 1900. Guichard (1, 2).
- 1901. Guichard.
- 1904. Guichard.
- 1905. Guichard (2).
- 1906. Guichard, Merlin (1, 2).
- 1909. Guichard (1, 2).

**N⁵2. COMPLEXES OF SPHERES
AND HYPERSPHERES. (For
application of n dimensions to com-
plexes of spheres in S_3 , see Q2ca.)**

N⁵3. COMPLEXES OF CURVES.

- 1901. Kantor (5).
- 1902. Kantor (2).
- 1904. Bordiga.
- 1905. Greul.
- 1908. Godeaux.

N⁶. CONNEXES.

- 1904. Autonne.
- 1908. Veneroni.

N⁷. OTHER ANALOGOUS SYSTEMS.

- 1908. Scorza (3).

**N⁸. NON-LINEAR SYSTEMS IN n
DIMENSIONS; ENUMERATIVE
GEOMETRY.**

**N⁸1. SYSTEMS OF VARIETIES IN
 S_n .**

- 1897. Moutard.
- 1910. Segre.

N⁸2. Enumerative geometry.

**N⁸2a. FORMULAE OF INCIDENCE AND
COINCIDENCE; PRINCIPLES OF
CORRESPONDENCE.**

Linear spaces.

- 1877. d'Ovidio (2).
- 1884. Schubert (2).
- 1885. Schubert (1).
- 1886. Schubert (1, 2).
- 1888. Segre (1).
- 1889. Castelnuevo (3), Lands-
berg.
- 1890. Pieri (1).
- 1891. Schubert (1, 2).
- 1892. Amodeo (2), Schubert.
- 1893. Pieri.
- 1900. Severi (2).
- 1901. Kantor (3), Palatini (1,
2).
- 1903. Giambelli (1, 2), Schu-
bert (1-4).
- 1904. Caspar, Giampaglia,
Perazzo.
- 1905. Giambelli (2).
- 1907. Sommerville (1).

Polytopes.

- 1902. Schubert.

Curves. (Multisecants, &c.)
(*Ref. M⁵1b.*)

- 1889. Castelnuevo (1).
- 1895. Berzolari (2).
- 1900. Severi (1), Tanturri (1).
- 1902. Crepas.
- 1903. Crepas.
- 1909. Giambelli.

Conics and quadrics.

- 1889. Schubert.
- 1890. Burali-Forti, Schubert.

1891. Schubert (2).
1894. Schubert.
1897. Schubert.

Spaces of higher degree than the second.

1885. Schubert (2).
1891. Pieri (1).
1892. Pieri.
1897. Pieri (2).
1899. Rosati.
1900. Tantarri (2).
1903. Severi (1).
1909. Fano, Pannelli.

N^o2d. ORDER OF A LOCUS OR CLASS OF AN ENVELOPE.

1900. Segre.
1903. Giambelli (3).
1904. Giambelli.
1909. Palatini (1).

N^o2e. ORDER OF A COMPLEX OR A RULED SURFACE.

1903. Marletta (1).

N^o2g. NUMBER OF STRAIGHT LINES SATISFYING GIVEN CONDITIONS.

1909. Palatini (2).

N^o2j. NUMBER OF QUADRICS SATISFYING GIVEN CONDITIONS.

1900. Schoute (1).
1905. Toxopeus.
1906. Sommerville (1).

N^o2l. NUMBER OF FIGURES OF A GIVEN SPECIES SATISFYING GIVEN CONDITIONS.

1902. Severi (3), Tantarri (1, 2).

O². INFINITESIMAL AND KINEMATIC GEOMETRY OF n DIMENSIONS.

1906. Tichomandrickij.
1909. Sforza (2).

O²1. Curves in S_n .

1874. Jordan (1).
1880. Hoppe (1).
1881. Brunel.
1882. Craig.
1888. Hoppe.
1889. Brunn.
1890. Pirondini.
1891. Meyer.
1897. Berzolari (1).
1898. Piccioli, Sayre.

1902. J. G. Hardy, Hatzidakis.
1906. Herglotz.
1908. Lebedev, Pirondini.
1910. Rath.

Curvature and torsion.

1878. Fromm.
1890. Pirondini.
1892. Hoppe.
1895. Landsberg.
1900. Lovett (1), Rath, Richmond (4), Schoute (3).
1903. Sincov.
1904. Wildervanck.

Curves of constant curvature or torsion.

1881. Brunel.
1900. Piccioli.
1901. Piccioli (2).

Intrinsic geometry.

1888. Cesàro (4).
1889. Cesàro (1).
1896. Cesàro.
1897. Landsberg.
1900. Lovett (1, 3).
1904. Cesàro (2, 3).

O²2. Varieties of $n-1$ dimensions in S_n .

1871. Lie (2).
1890. Pirondini.
1895. Ricci.
1896. Bianchi (1).
1898. Sayre.
1900. Kowalewski, Ricci and Levi-Civita.
1902. Ricci (1).
1905. Bocchetta (2).
1907. Segre (2).
1908. Dall'Acqua, Lebedev.

Measure of curvature. (For transformation of the quadratic differential form *see* **C4d**.)

1867. Morin.
1869. Lipschitz (1, 2).
1871. Lie (1), Suvorov.
1874. Beez, Jordan (2).
1875. Beez (2).
1876. Allé, Lipschitz (1-3).
1877. Gosiewski (*see* Riemann).
1879. Beez.
1880. Hovestadt, Voss (1, 2).
1881. Donadt.
1882. Craig, Lipschitz.
1884. Ricci.
1886. Hoppe (1).
1887. Padova.

- 1889. Mlodzejevskij, Ricci.
- 1897. Hadamard (2).
- 1902. Ricci (1), Servant (2).
- 1903. Kühne (1, 2).
- 1906. Maschke (2).

Lines traced on a variety, expression for ds^2 ; formulæ of Codazzi.
(*Ref. C4d.*)

- 1868. Beltrami (2).
- 1869. Kronecker, Lipschitz (1).
- 1883. Lipschitz.
- 1894. Cesàro (2).
- 1897. Berzolari (2).
- 1898. Berzolari (1, 2).
- 1899. Buchholz.
- 1903. James.
- 1904. Cesàro (3).
- 1905. Mahlo.

Geodesic lines, &c.

- 1868. Beltrami (2).
- 1872. Lipschitz (1).
- 1901. Engel, Hadamard.
- 1902. Finzi.
- 1903. Boulanger, Ricci (2).

Spherical representation.

- 1868. Beltrami (2).
- 1872. Beltrami (1), Schläfli.

Differential invariants.

- 1898. Lovett (1).
- 1899. Cotton (1), Forsyth.
- 1903. Rothe (1, 2).
- 1904. Ricci (2), Rothe.
- 1905. Sinigallia, Wright.
- 1906. Maschke (1, 2).

Minimal surfaces.

- 1872. Lipschitz.
- 1888. Padova (1).
- 1889. Mlodzejevskij.
- 1898. Guichard (4).
- 1905. Kommerell.
- 1908. E. E. Levi.

Deformation of varieties; applicable varieties.

- 1878. Cayley, Monro (1, 2), Newcomb (1).
- 1880. Voss (1).
- 1881. Donadt.
- 1884. Ricci.
- 1886. Hoppe (1), Schur (2, 3).
- 1889. Padova (1).
- 1892. Puchta (1, 2).

- 1894. Stäckel.
- 1895. Cesàro.
- 1898. Bianchi, Campbell.
- 1899. Banal, Liebmann (1), Mannoury (1).
- 1900. Liebmann (2).
- 1901. Liebmann (1).
- 1902. Fouché, Kühne.
- 1903. James.
- 1905. Bianchi (1), Fubini (3).
- 1908. Sbrana.
- 1909. Sbrana.

Orthogonal systems.

- 1869. Darboux.
- 1871. Lie (1, 2).
- 1886. Pieri, Ricci.
- 1896. Cesàro, Ricci.
- 1897. Drach, Guichard (1), Ricci (1).
- 1898. Darboux.
- 1899. Pellet (2).
- 1900. Pellet.
- 1902. Darboux.
- 1905. Rath.
- 1908. Drach.

Curvilinear coordinates.

- 1907. Riquier.

Cyclic systems. (*Ref. N⁵¹.*)

- 1897. Guichard (1, 3).
- 1905. Sbrana.
- 1906. Sbrana (1).

Ruled varieties.

- 1901. Kühne.

Developable varieties.

- 1892. Puchta (1).

Varieties of constant (zero) curvature.
(*Ref. Q1a β .*)

- 1889. Ricci.
- 1895. Banal.
- 1896. Banal.
- 1897. Banal.

Guldin's rule for volume of variety of revolution.

- 1904. Schoute (5).

Osculating spheres, &c.

- 1893. Hoppe.

Singularities.

- 1904. Saurel.

O²3. VARIETIES OF $n-k-1$ DIMENSIONS IN S_n ($0 < k < n-2$).

(α signifies surfaces, $k=n-3$.)

- 1897. α Kommerell.
- 1904. α Cesàro (3), Eiesland.
- 1905. Eiesland, Kommerell.

O²4. KINEMATIC GEOMETRY OF n DIMENSIONS.

- 1897. Landsberg.
- 1900. Hatzidakis (2).
- 1902. J. G. Hardy.

Envelopes.

- 1887. Hilbert.
- 1905. Bottasso.
- 1907. Scorza.

Varieties of translation (generated by a moving curve).

- 1892. Lie (1).
- 1893. Scheffers (3).
- 1896. Lie.
- 1897. Lie.
- 1901. Poincaré (3).

P². GEOMETRICAL TRANSFORMATIONS IN S_n .

P²1. HOMOGRAPHY AND HOMOLOGY.

- 1874. Eichler.
- 1880. Kantor.
- 1884. Segre (2).
- 1888. Loria (4).
- 1891. Aschieri (1, 2).
- 1895. Kohn (1), Waelsch.
- 1896. Del Re (1), Pincherle (2), Visalli.
- 1898. Lovett (1), Muirhead.
- 1899. Cazzaniga, Del Prete.
- 1900. Moore (2).
- 1901. Burnside (1, 2).
- 1903. Berzolari (2), Kohn, Lorenzola, Wilson (2).
- 1904. Fubini (4).
- 1905. Autonne (1), Berzolari, Brusotti, Natucci (2).
- 1906. Guareschi, Haskell, Kowalewski (2).
- 1907. W. F. Meyer (2), Reichel.
- 1908. Barrau (1), Wilson (1, 2), Young.
- 1909. Kohn, Kruppa, Wernicke, Young.

P²1c. HOMOGRAPHY.

- 1884. Segre (2).
- 1885. Aschieri, Segre (2).
- 1886. Aschieri (1), Bertini (1), Bordiga (1), Segre (1).
- 1887. Bertini (1, 2).
- 1889. Predella.
- 1890. Del Re (2), Enriques.
- 1891. Aschieri (1, 2).
- 1892. Enriques (1, 2), de Paolis, Predella.
- 1893. Deruyts.
- 1897. Bordiga (2).
- 1901. Leonardi.
- 1906. Medici.
- 1907. Del Re, Wilson.

P²1d. HOMOLOGY.

- 1887. Bertini (2).
- 1900. Monti.
- 1907. Del Re.

P²1f. GENERALITIES ON PROJECTIVE PROPERTIES.

- 1890. Segre.
- 1892. Sforza.
- 1893. Zindler.
- 1897. Del Prete.
- 1901. Burnside (3).
- 1906. Marletta (2).

P²2. CORRELATIONS AND TRANSFORMATIONS BY RECIPROCAL POLARS.

- 1870. Cayley (2).
- 1881. Rosanes.
- 1886. Visalli.
- 1890. Hirst.
- 1892. Fontené.
- 1895. Waelsch.
- 1896. Del Re, Visalli.
- 1902. Palatini, Schoute (3).
- 1903. Giambelli (2).
- 1906. Kowalewski (1, 2), Medici.
- 1909. Ogura.

P²3. ISOGONAL TRANSFORMATIONS.

- 1875. Beez (1).
- 1879. Craig (1).
- 1885. Sachs.
- 1896. Del Re.
- 1897. Cotton.
- 1898. Cotton.
- 1903. Finzi, Voss.
- 1905. Fubini (2).
- 1908. Bateman.
- 1909. Bateman, Fubini (2).

P²4. BIRATIONAL TRANSFORMATIONS.

- 1884. Veronese (1).
- 1885. de Paolis (2).
- 1890. Del Re (1).
- 1893. Ascione (1), Chizzoni.
- 1896. Del Pezzo (1).
- 1897. Montesano.
- 1898. Carrone.
- 1901. Kantor (6), Veneroni.
- 1904. Perazzo.
- 1906. Pannelli (2).

P²4b. QUADRATIC TRANSFORMATIONS.

- 1894. Kantor (1, 2).

P²4c. CREMONA TRANSFORMATIONS.

- 1896. Del Pezzo (2).
- 1897. Autonne (1), Del Pezzo, Fano (1).
- 1900. Moore (1).
- 1905. Autonne (2).
- 1909. Godeaux.

P²5. REPRESENTATION OF ONE VARIETY UPON ANOTHER.

- 1882. Craig.
- 1888. Del Re (1).
- 1892. Kühne.
- 1899. Cotton (1).
- 1908. Fano (1).

Correspondence between manifolds of different dimensions. (*Cf.* J5b.)

- 1877. Cantor.
- 1878. Netto.
- 1879. Cantor (1, 2).
- 1883. Cantor (1-5).
- 1891. Giudice.
- 1892. Milesi.
- 1896. Schoenflies.
- 1899. Lüroth.
- 1904. Del Giudice.
- 1906. Bolza, Lüroth, Severini.
- 1907. Baire.
- 1908. Sierpinski, Tietze.
- 1909. Mahlo.

P²6. VARIOUS TRANSFORMATIONS.

- 1887. Pieri.
- 1895. Berzolari, Brill, Hadamard (1).
- 1900. Smith.
- 1906. Clairin.
- 1907. Young.
- 1908. Barrau (1), Carda.

P²6a. RATIONAL TRANSFORMATIONS.**P²6b. TRANSFORMATIONS BY RECIPROCAL DIRECTIONS; TRANSFORMATION OF BONNET.**

- 1906. Bricard (1, 2), Butin.

P²6c. INVOLUTIONS.

- 1891. Montesano.
- 1904. Colombi.

P²6d. TRANSFORMATIONS OF STRAIGHT LINES INTO SPHERES.

- 1899. Lovett (3, 4).

P²6e. CONTACT TRANSFORMATIONS.

- 1884. Engel.
- 1888. Fitting, Lie.
- 1889. Lie (1, 2).
- 1898. Lie, Lovett (3).
- 1899. Liebmann (2), Lovett (5).
- 1900. Lovett (4).
- 1901. Engel.
- 1902. Lovett.
- 1905. Dohmen.
- 1906. Brüggmann, Engel, Vesiot.
- 1909. Lattès (1, 2).

P²6f. VARIOUS TRANSFORMATIONS.

- 1903. Marletta (2, 3).
- 1904. Aschieri, Marletta (1).
- 1906. Hadamard (1, 2).

Q1. NON-EUCLIDEAN GEOMETRY, FOUNDATIONS OF GEOMETRY, THEORY OF PARALLELS.

(*n* prefixed signifies *n* dimensions.)

Generalities on non-euclidean geometry.

- 1863. Hoüel.
- 1867. Hoüel.
- 1870. Hoüel (2), Massimino.
- 1876. Tannery.
- 1877. Frischauf, Genocchi (1, 2), Gerlach, Halsted, Killing.
- 1878. Grassmann, Spottiswoode.
- 1879. Schlegel.
- 1880. Halsted.
- 1882. Lane.
- 1883. Ball (1), Carbonnelle, Cayley, Dauge, Most.
- 1884. Fabra, Killing, Quensen, Schmitz.

1888. Beez, Frasnighi, Milhaud.
1889. Benucci, Calinon, Lechallas, Mansion.
1890. Broglie, Duclout, Halsted, Lechallas (3), Simon (1), Vivanti.
1891. Calinon, Halsted (1), Lechallas (1, 2), Mansion (1), Poincaré, Rouché, Simon (1, 2), Study.
1892. W. W. R. Ball, de Tilly.
1893. Halsted (2), Mansion (1, 2), Newcomb, de Tilly.
1894. Halsted (3), Klein (1), Suworov (*see* Anon.).
1895. de Galdeano, Hadamard (2), La Vallée Poussin, Mansion (4), Neovius, Simon and Kriesling.
1896. de Galdeano, Gallucci, Halsted (1, 4), Nekrasov, Janssen van Raaij (2).
1897. Dupuis, Macaulay, Mansion (2), Reinhardt, Story.
1898. Halsted (1, 3-5), Mansion (5, 6), Newcomb.
1899. Fontené (1), de Galdeano.
1900. Andrade (2), Bonola (2), Halsted (3), Kölmel, Monck, Study (2), Woods.
1901. Barbarin (1), Crawley, Frasnighi, Halsted (1, 2, 4), Mansion (3).
1902. Halsted (4, 6), Laurent (2), Newcomb, Poincaré (4), Study (2).
1903. Bonola (1), Combebiac, Haldane, Mach, Mansion (1), Moliné, Poincaré (1), Russell.
1904. Darboux (1), Halsted (2), Hinton (2), Lechallas (1, 3), Miller.
1905. Bordage, Halsted (3), Mansion (3), Nelson, Vahlen.
1906. Enriques, Faigl, Geissler (3).
1907. Halsted, Mansion (2), Sittignani.
1908. Carus (2), Chase, Montverde, Rust, Warrain.
1909. Alasia, Halsted (1, 2), Zimmermann.
1910. Lipke, M'Coll.
- General expositions of non-euclidean geometry. (*Fortreatises see* V1a κ).
1880. Chrystal, Killing (1).
1881. Cox.
1882. Cox.
1883. Ball (1), n Killing (2).
1884. Buchheim (1).
1889. Klein (1).
1892. M'Clintock.
1893. Kagan.
1894. Halsted (1).
1896. Mansion (5).
1898. Fano (3), Villarreal, Whitehead (1).
1902. Russell.
1904. Lechallas (3).
1905. Calisse, Massau, Vahlen.
1906. Halsted, Massau.
1907. Enriques (2), Bonola (*see* Enriques 3 (8)).
1910. Russell and Whitehead.
1911. Liebmann (*see* Auerbach).
- Adverse criticisms of non-euclidean geometry. (*Ref.* Q1a α , V1d.)
1870. Carton.
1873. Genocchi.
1877. Pietzker (1, 2).
1878. Gilles.
1888. Bonnel, de Communes.
1889. de Communes, Renouvier.
1890. Broglie, Varisco.
1892. Renouvier.
1893. Karagiannides, Lechallas.
1894. Philippov.
1895. Bonnel.
1896. Dauge (2).
1897. Bolland, Novikov.
1899. Lagrange.
1900. Frolov (1, 2), Tichoman-drickij, Vidal.
1902. Issaly, Vidal.
1903. Delaporte, Richard, Vidal.
1904. M'Coll.
1905. Delsol, Frolov.
1906. Rabinovitch.
1907. Wickersheimer.
- Relation between non-euclidean geometry and geometry on surfaces of constant curvature. (*Ref.* Q1a β , γ). α the distinction enforced, β the two identified.
1888. β Beez.
1896. β Dauge (2), β Lechallas (3), α Mansion (3, 8).
1898. β Dauge (1), α Mansion (2).
1901. β Lechallas (3).
1902. α Russell.
1904. β Lechallas (3).
1907. β Wickersheimer.

APPLICATIONS OF NON-EUCLIDEAN
GEOMETRY TO FUNCTION-THEORY.
(*Ref. Q1e β , Q1 (K9b).*)

Automorphic functions.

- 1881. Poincaré.
- 1882. Poincaré (1-4).
- 1883. Poincaré (2).
- 1890. Klein (2).
- 1897. Klein and Fricke (1).
- 1898. Schlesinger.
- 1899. Schlesinger (1).
- 1902. Schlesinger (2).
- 1903. Zühlke.
- 1908. Hilb, Poincaré (2).

Schwarzians.

- 1873. Schwarz.
- 1894. Kapteijn (1, 2), Schilling.
- 1895. Schilling.

Application of Hermitian forms and
homographic transformation with
conjugate complex variables; con-
form representation.
(*Ref. Q1 (P3b), Q1e β .*)

- 1890. Schwarz, Segre.
- 1891. Bianchi (1, 2), Segre (2).
- 1892. Bianchi, Segre (2).
- 1898. Loewy.
- 1899. Giudice.
- 1902. Schlesinger (2).
- 1904. Fubini (6-8).
- 1905. Bohler, Fubini (5), Lieb-
mann (1), Study.
- 1906. Guareschi.
- 1907. Poincaré (1), Study.
- 1910. Sommerville (3).

PHYSICAL APPLICATIONS.

- 1910. Varicak (1-3).
- 1911. Varicak, Wien (*see* Auer-
bach).

Q1. Non-euclidean geometry; special topics. (It is convenient here to combine hyperbolic and elliptic geometry, using the classification of the INDEX DU RÉPERTOIRE BIBLIOGRAPHIQUE for ordinary geometry. When a work deals exclusively with hyperbolic or exclusively with elliptic geometry this is indicated by the letters *b* and *c* respectively. *n* signifies *n* dimensions. For works of a general nature dealing exclusively with hyperbolic or elliptic geometry *see* **Q1b** and **Q1c**.)

(**B12c**). VECTORS.

- 1904. Davis.
- 1908. Andrade.

(**K**). GEOMETRY AND TRIGONO-
METRY.

- 1733. Saccheri.
- 1786. Lambert.
- 1829. *b* Lobachevsky.
- 1832. *b* J. Bolyai.
- 1835. *b* Lobachevsky (1, 2).
- 1840. *b* Lobachevsky.
- 1855. *b* Lobachevsky.
- 1867. *b* Battaglini.
- 1871. *b* Marie.
- 1872. *b* Frischauf.
- 1873. *n* Schering (1).
- 1875. Clebsch.
- 1876. Frischauf.
- 1877. *b* de Zolt.
- 1879. de Tilly.
- 1882. Story (1).
- 1890. Cayley (2).
- 1899. de Francesco (1), *b* Haus-
dorff, *bn* Mansion (1).
- 1901. Barbarin (2).
- 1902. *b* Bonnesen.
- 1905. Liebmann (1).
- 1906. *b* Privorsky.
- 1907. *b* Pérez del Pulgar, *b*
Privorsky.
- 1908. *b* Varicak (1, 2).
- 1909. *b* Pironcini, *b* Pund.
- 1910. Mollerup (2).

(**K1**). POINTS AND STRAIGHT LINES;
THE TRIANGLE. (For trigonometry
of the triangle *see* (**K20e**).)

- 1846. *c* Cayley.
- 1902. *b* Stäckel (5).
- 1903. *b* Szabó.
- 1906. Varicak (3).

Construction of parallels, &c. (*b*)

- 1872. Beltrami (3).
- 1890. Simon (2).
- 1897. Engel (1).
- 1898. Burnside (1).
- 1905. Liebmann (2).
- 1906. Liebmann.

(**K1a**). Elementary theory of trans-
versals.

- 1905. Ventura y Reyes.

(**K1b**). Relations between the lengths of
the sides of a triangle and certain
special lines.

- 1901. Wasteels (2).
- 1902. Barbarin (1), Wasteels.

- Relations between the distances of given points. (*See* Q1a γ .)
1891. Mansion (b1, 2).
1895. Mansion (5).
1896. Mansion (7).
- (K1c). Other theorems relating to the triangle.
1896. c Mansion (2).
- (K1d). Area and angle-sum of a triangle.
1829. b Lobachevsky.
1833. Legendre.
1844. Meikle.
1864. Kelland.
1895. b Kagan (2).
1896. c Stouff.
1900. Veltmann.
- (K2). POINTS, STRAIGHT LINES, TRIANGLES AND CIRCLES.
- (K2c). The nine-point circle.
1878. b Frattini.
1886. b Ricordi.
- (K3). SPECIAL TRIANGLES.
- (K3a). Isosceles triangle.
1901. Wasteels (1).
1902. Blichfeldt (2).
- (K3c). Right-angled triangle; theorem of Pythagoras.
1893. b Semikolenov.
1896. Traub.
1897. Reyes y Prósper (2).
1909. Barbarin.
- (K4). CONSTRUCTION OF TRIANGLES.
1897. b Simon (2).
1901. b Liebmann (3).
1904. Fontené, b Grossmann (1, 2).
1905. Simon.
- (K5). SYSTEMS OF TRIANGLES.
- (K6). ANALYTICAL GEOMETRY; COORDINATES.
1881. Cox.
1882. Cox.
1901. Barbarin (2).
1906. b Varicak.
1908. b Varicak (2).
- Biaxial (Cartesian) coordinates.
1829. b Lobachevsky.
1835. b Lobachevsky.
1836. b Lobachevsky.
1855. b Lobachevsky.
- Polar coordinates.
1835. b Lobachevsky (1).
1855. b Lobachevsky.
- Weierstrass' coordinates.
1885. n Killing.
- Line-coordinates.
1902. Hudson.
- (K7). ANHARMONIC RATIO; HOMOGRAPHY.
1874. Escherich.
- (K8). THE QUADRILATERAL.
- (K8b). Quadrilateral inscribed in a circle.
1909. Cailler.
- (K8f). Birectangular.
1733. Saccheri.
1786. Lambert.
1902. Barbarin (3).
- Trirectangular.
1901. Barbarin (2), Mansion (4).
1904. b Bonola.
- (K9). POLYGONS.
- (K9aa). Area.
1882. Story (2).
1900. Veltmann.
1906. Liebmann.
- (K9b). Regular polygons.
1902. Barbarin (4).
- Division of the plane by regular polygons. (For division of non-euclidean space by polyhedra *see* Q1 (K14g); for division of S_n by polytopes *see* K²4g).
- (Application of Automorphic functions α , Schwarzians β , Group-theory γ .)
1873. β Schwarz.
1882. γ Dyck, α Poincaré (1-4).
1883. Hess, α Poincaré (2), Schlegel (1).
1885. c Hess.
1890. α Klein (2).
1891. γ Bianchi (1, 2).
1892. γ Bianchi (1, 2).
1894. β Kapteijn, β Schilling.
1895. β Schilling.
1896. $c\gamma$ Maschke (1, 2).
1897. γ Burnside, γ Fricke.
1905. Sommerville.

- (K10). THE CIRCLE, α limit-curve, β equidistant.
 α . 1889. Reina.
 1899. Mansion (2).
 β . 1733. Saccheri.
 1786. Lambert.
 1796. Legendre.
 1900. Crivetz.
 1908. b Varicak (3).
- (K10b). Construction of tangent.
 1894. α Simon.
- (K10c). Circumference and area.
 1835. b Lobachevsky.
- (K11). SYSTEMS OF CIRCLES.
 1908. Mercatanti.
- (K12). CONSTRUCTION OF CIRCLES.
 1874. Battaglini (2).
 1880. Ricordi.
 1901. Vlasov.
- (K13). POINTS, STRAIGHT LINES AND PLANES; THE TETRAHEDRON.
- (K13a). General; dihedral angles.
 1840. b Lobachevsky.
 1873. d'Ovidio (1), Stahl.
 1893. n d'Ovidio (1).
 1897. b Simon (2).
 1899. b Simon.
 1901. Barbarin (3).
 1910. b Sommerville (2).
- Equidistant (non-coplanar) straight lines in elliptic space (Clifford's parallels.)
 1873. Clifford, Lindemann.
 1879. Ball.
 1884. Buchheim (1).
 1890. Klein (1).
 1900. Petersen.
 1902. Study (2).
 1904. Bianchi (5), Fubini (1).
 1906. Study (1).
 1907. Study.
 1909. Bouman (1, 2), Brouwer (2), Vogt.
- (K13c). The Tetrahedron.
 1899. c Berry.
 1905. Mansion (1).
- Volume.
 1829. b Lobachevsky.
 1835. b Lobachevsky.
 1836. b Lobachevsky (1).
 1873. d'Ovidio (1), Stahl.
1893. d'Ovidio (1).
 1903. Frischauf, c Richmond (2).
 1905. b Frischauf.
- (K14). POLYHEDRA.
- (K14d). Areas and volumes.
 1835. b Lobachevsky.
 1836. b Lobachevsky (1).
 1902. Reiter, Šatunovskij.
 1904. b Dannmeyer.
 1908. Sforza (2, 3).
- (K14g). Division of space by regular polyhedra.
 1885. c Hess.
 1886. c Hossfeld.
 1889. c Goursat.
 1891. Schlegel (1).
 1893. Bianchi (1, 2).
 1895. c Hess.
 1898. c Hess.
 1909. Bianchi.
- (K15). CYLINDER AND CONE.
 Volume.
 1829. b Lobachevsky.
 1835. b Lobachevsky.
 1836. b Lobachevsky (1).
 1876. b Frank.
 1885. Quensen.
- (K16). THE SPHERE, α limit surface, β equidistant.
- (K16a). General.
 1905. b Fischer, Fubini (2).
 1908. β Varicak (4).
- (K16g). Volume.
 1829. b Lobachevsky.
 1835. b Lobachevsky (1).
 1836. b Lobachevsky (1).
 1876. ba Günther (1).
 1881. Aschieri.
 1899. α Mansion (2).
- (K18). SYSTEMS OF SPHERES.
 1894. ba Simon.
 1907. n Bateman and Sommerville.
- (K20). TRIGONOMETRY.
 Parallel-angle and the function $\Pi(p)$.
 1870. Grunert.
 1896. Janssen van Raaij.
 1898. Engel (1).
 1903. Kürschák.
 1905. Liebmann (2).

(K20e). Formulæ for plane triangles.

- 1829. *b* Lobachevsky.
- 1832. *b* J. Bolyai.
- 1835. *b* Lobachevsky (1).
- 1836. *b* Lobachevsky (1).
- 1840. *b* Lobachevsky, Minding.
- 1865. *b* Cayley.
- 1870. *b* Grunert.
- 1872. *b* Cayley.
- 1873. *d*'Ovidio (1).
- 1875. *b* Réthy.
- 1876. *b* Réthy.
- 1881. Story.
- 1882. Story (2).
- 1884. *b* Cayley.
- 1892. *b* Gérard, *b* Simon.
- 1893. *b* Gérard.
- 1895. *b* Kagan (1).
- 1897. Mansion (3).
- 1899. Stringham.
- 1900. *b* Efimov.
- 1903. *b* Mansion (2), *b* Petersen.
- 1905. *b* Bonola (3), *b* Liebmann (2).
- 1907. *b* Liebmann.
- 1909. *b* Reyes y Prósper.

(K21). VARIOUS QUESTIONS.

- 1887. Bang.

(K21aa). Constructions with the ruler alone.

- 1892. *b* Gérard.
- 1899. *c* Barbarin (1).
- 1910. *b* Grossmann.

(K21b). Division of the angle.

- 1903. *b* Liebmann (1).
- 1908. Grigoriev.

(K22). DESCRIPTIVE GEOMETRY.**(K23).** PERSPECTIVE.**(K23a).** Conical perspective.

- 1905. *b* de Vries (2).

(L¹). CONICS.

- 1901. Barbarin (2).
- 1902. Liebmann (2).
- 1910. Coolidge.

(L¹1). GENERALITIES.

- 1873. *c* Voigt.
- 1882. Story (3).
- 1910. *c* Naranienagar.

(L¹1a). Classification.

- 1873. *b* Frank.
- 1874. Escherich.
- 1882. Story (3).
- 1901. Barbarin (2).
- 1906. Bromwich.

(L¹3). CENTRES, DIAMETERS, AXES AND ASYMPTOTES.

- 1882. Story (3).
- 1891. *d*'Ovidio (3).

(L¹7). FOCI AND DIRECTRICES.

- 1869. *c* Clifford (and Cayley).
- 1882. Story (3).
- 1891. *d*'Ovidio (1).
- 1893. *d*'Ovidio (1).
- 1900. Stringham (1).

(L¹17). PROPERTIES RELATIVE TO TWO OR MORE CONICS.

- 1874. Battaglini (1).

(L¹19). CONFOCAL CONICS.

- 1891. *d*'Ovidio (2).

(L²). QUADRIC SURFACES.**(L²1a).** Classification.

- 1901. Barbarin (2).
- 1903. Bonola (2), *b* Coolidge.
- 1905. Bromwich.
- 1906. Bromwich.

(L²2). CONES AND CYLINDERS.

Clifford's surface in elliptic space.

- 1873. Clifford.
- 1884. Buchheim (1).
- 1890. Klein (1).
- 1896. Bianchi (2).
- 1901. Manning.
- 1909. Bouman (1, 2), Brouwer (2), Vogt.

(L²9). FOCALS.

- 1902. *c* Linneborn.
- 1903. Bonola (2).

(L²10). CONFOCAL QUADRICS.**(L²10d).** Corresponding points; Ivory's theorem.

- 1903. A. L. Dixon.

(L²11, 12). LINES OF CURVATURE; GEODESICS.

- 1873. Stahl.

- (L²18). SYSTEMS OF THREE QUADRICS.
1874. Battaglini (3).
- (L²21c). Quadrics of revolution.
1900. Bianchi (1).
1901. Bianchi.
- (M). ALGEBRAIC CURVES AND SURFACES.
- (M¹1b, 3 α , i β). Multiple points; evolutes; parallel curves.
1871. Cayley.
- (M²4f). Cyclides.
1906. Munich.
- (N). COMPLEXES AND CONGRUENCES.
- (N¹1). COMPLEXES OF LINES.
1875. d'Ovidio (2).
1876. d'Ovidio (1-3).
1881. Aschieri, d'Ovidio.
1895. Fibbi.
1900. Petersen.
1905. Beck.
1910. Beck, Coolidge.
- (N²1). CONGRUENCES OF LINES.
1875. d'Ovidio (2).
1876. d'Ovidio (1).
1896. Bianchi (2).
1900. Study (2).
1904. Bianchi (4, 5), Coolidge (1), c Fubini (1).
1905. Guichard (2).
1906. Study (1).
1909. Vogt.
- (N²3). CONGRUENCES OF CURVES.
1899. Dall'Acqua.
1901. Dall'Acqua.
- (O). INFINITESIMAL GEOMETRY.
1894. Rath.
1910. Coolidge.
- (O2). PLANE CURVES.
1910. Coolidge.
- (O2a). Area.
1892. b Gérard.
- (O2q β). Caustics.
1907. Pirondini.
- (O3). TWISTED CURVES.
1899. b Razzaboni.
1900. n Rath.
1908. c Razzaboni.
1909. Hostinsky.
1910. Coolidge.
- (O4). RULED SURFACES. (*Ref.* (L²2).)
1900. c Gigli.
1901. Barbarin (2).
1910. Coolidge.
- (O5). SURFACES IN GENERAL AND CURVES TRACED ON SURFACES.
1910. Coolidge.
- (O5a). Volumes.
1835. b Lobachevsky (1).
1836. b Lobachevsky (1).
1893. b Simon.
1897. Mansion (6).
1902. v. Mangoldt.
1903. Barbarin.
1904. b Dannmeyer.
1908. Sforza (1).
1909. n Sforza (2).
- (O5b). Areas.
1893. b Semikolenov.
1904. b Dannmeyer.
- (O5d). Principal radii of curvature.
1888. Bianchi (1).
- (O5e). Curves traced on surfaces; formulæ of Codazzi.
1901. Servant.
- (O5h). Lines of curvature.
1873. Darboux.
- (O5i). Surfaces whose lines of curvature satisfy given conditions.
1905. c Fubini (4).
1906. Sbrana (2).
- (O5i β). Surfaces whose lines of curvature form isothermal systems.
1903. Bianchi (3).
- (O5l). Geodesics.
1873. Darboux.
1901. Barbarin (2).
- (O6). SYSTEMS OF SURFACES.
- (O6a). Helicoids.
1907. Study.
- (O6aa). Surfaces of revolution.
1904. b Dannmeyer.
1909. Sforza (1).

(O6g). Surfaces of constant curvature.
Surfaces of zero curvature.

(Ref. Q1 (K16a, L²2).)

- 1895. c Bianchi.
- 1896. c Bianchi (2).
- 1898. Whitehead (2).
- 1899. Bianchi.
- 1902. c Bianchi (2).
- 1908. b Böhm.

(O6h). Minimal surfaces.

- 1887. Bianchi (2).
- 1890. Cayley (1).
- 1896. Guichard (2).
- 1900. Servant.
- 1906. Schübel.

(O6k). Deformation of surfaces.

- 1878. Bianchi.
- 1899. Bianchi, Fubini.
- 1900. Bianchi (1), c Gigli.
- 1901. Bianchi.
- 1902. c Bianchi (2).
- 1904. c Fubini (3).
- 1905. Bianchi (2), Demoulin-
(1), Guichard (2).

(O6m). Isothermal surfaces.

- 1900. Servant.
- 1901. c Fubini.
- 1905. Bianchi (2, 3).

(O6p). Orthogonal systems.

- 1887. Bianchi (1).
- 1888. Bianchi (2).
- 1896. Bianchi (2).

(O7d). Cyclic systems.

- 1906. Sbrana (1).

(P). GEOMETRICAL TRANSFORMATIONS.

- 1906. b Varicak (1).

(P1a). HOMOGRAPHY.

- 1907. Meyer (3).

(P3). ISOGONAL TRANSFORMATIONS.

(P3a). General.

- 1905. Fubini (2).
- 1908. Coolidge.

(P3b). Inversion.

- 1902. b Liebmann (1).
- 1904. Ludwig.

(P3ca). Transformation of Moebius.

- 1876. Battaglini.

(P5b). REPRESENTATION OF ONE SURFACE ON ANOTHER.

- 1902. Servant (1).
- 1904. Bianchi (1, 2).

(P6). VARIOUS TRANSFORMATIONS.

- 1900. Stringham (2).
- 1908. Coolidge.

(P6e). Contact transformations.

- 1900. Clairin.
- 1904. Study.
- 1908. Ludwig.

Q1a. THE FOUNDATIONS OF GEOMETRY; SYSTEMS OF AXIOMS, &c. (For treatises see V1a_c.)

General.

- 1844. Grassmann.
- 1863. Hoüel.
- 1867. Hoüel.
- 1870. Bonnel.
- 1873. Cassani.
- 1874. Bonnel, Liard, Wagner.
- 1875. Becker, Clebsch.
- 1876. Frischauf.
- 1879. Becker.
- 1882. Cassani.
- 1883. Dauge.
- 1886. Bettazzi.
- 1890. Schotten.
- 1891. Iselin, Spaczinski, Veronese, Wiener.
- 1893. de Galdeano.
- 1894. Love (2), Veronese (2), Wiener.
- 1897. Russell, Veronese (2).
- 1898. Aleksejevskij, Poincaré (1).
- 1900. Enriques.
- 1901. Kagan, Petersen (2).
- 1902. Lewyckij.
- 1903. Moore, Russell, Stecker.
- 1904. Combebiac, Couturat (1), Hessenberg (2), Lechailas (1), Macaulay (2), Palatini, Sornetin.
- 1905. Combebiac (2, 3), Dickstein, Kasner (1), Liebmann (3), Segre (1).
- 1906. Andrade (1, 2), Laurent (2).
- 1907. Enriques (2).
- 1908. Combebiac (1), Gorka, Tannery.
- 1909. Schur.

- Nature of the point.
 4th cent. B.C. Aristotle (2).
- Definition of straight line.
 4th cent. B.C. Plato.
 1700. Leibniz.
 1905. Halsted (5).
 1908. Heath.
- Definition of straight line and plane
 by means of sphere.
 1795. Fourier.
 1806. Grashof.
 1832. W. Bolyai.
 1833. Thompson.
 1834. Thompson.
 1835. Lobachevsky (2).
 1851. W. Bolyai.
 1876. Frischauf, Günther (1).
 1879. Becker.
 1893. Schmidt.
 1896. Nazimov.
- Examination of the fundamental
 ideas of the straight line and plane,
 &c.
 1844. Newman.
 1845. Erb.
 1863. Höüel.
 1867. Höüel.
 1877. Becker (1), Cassani.
 1879. Tirelli.
 1880. Cassani, Killing (2).
 1888. Calinon.
 1889. Bonnel (2).
 1894. Palatini.
 1901. Petersen (1).
 1904. Poincaré (4).
 1905. Lambert, Wellstein.
 1907. Amaldi (*see* Enriques 3
 (3)).
 1908. Heath.
- The fundamental theorem of the
 plane.
 1829. Gauss.
 1834. Crelle.
 1844. Grassmann.
 1869. Valeriano.
 1883. Petersen.
 1901. Kool, Mansion (1), Wol-
 kow.
 1904. Gauss.
 1906. de Tilly.
 1908. Heath.
- Straight line as shortest path.
 1895. Hilbert.
 1900. Hilbert (2).
1901. Hamel.
 1903. Hamel.
 1905. Halsted (5).
- Definition of angle.
 1902. Petrini.
 1906. Bliss.
- Notion of area and volume. (*Ref.*
J5b.)
 1902. Lebesgue.
 1903. Lebesgue, Osgood, Wil-
 son (1, 2).
 1904. Ames.
- EQUIVALENCE OF FIGURES BY DIS-
 SECTION INTO A FINITE NUMBER OF
 CONGRUENT PARTS.
- Plane polygons.
 1890. Réthy.
 1892. Gremigni.
 1893. Dobriner (1, 2), Gremigni,
 Rausenberger, Réthy,
 Schur.
 1894. Biasi, Gremigni, Palatini,
 Réthy.
 1895. Frattini, Gremigni (1, 2),
 Lazzeri, Palatini (2),
 Sforza, Veronese.
 1896. Biasi, Bricard, Brunel.
 1897. Lazzeri, Mansion (5).
 1898. Kürschák.
 1903. Biasi, Csillag.
 1905. Dehn (1), Lennes.
 1906. Toffoletti.
 1907. Amaldi (*see* Enriques 3
 (6)).
- Polyhedra.
 1893. Rausenberger.
 1896. Bricard, Brunel.
 1897. Sforza.
 1900. Dehn (2), Hilbert (2).
 1901. Dehn.
 1902. Reiter, Šatunovskij, Vah-
 len (2).
 1903. Juel (1-3), Kagan (2),
 Šatunovskij, Vogt.
 1904. Dehn, Vogt.
 1905. Amaldi (2), Lennes.
 1907. Amaldi (*see* Enriques 3
 (6)).
- Examination of the symmetry of the
 plane (Euc. i. 5) without using
 three dimensions.
 1895. Tarry.
 1900. Barbarin (2), Bonnesen,
 Tarry.

- 1901. Tarry, de Tilly (2), Was-
teels (1).
- 1903. A. C. Dixon, Grigoriev,
Hilbert (2), de Tilly.
- 1904. Gauss, Mollerup.

FOUNDATIONS OF EUCLIDEAN GEO- METRY.

General.

- 1877. Becker (1).
- 1879. de Tilly.
- 1882. Pasch.
- 1884. de Paolis.
- 1890. Andrade, Brodén, Lecha-
las (2).
- 1891. Dixon, Veronese, Wiener.
- 1893. Delbœuf (1).
- 1895. Burkhardt, Hilbert.
- 1897. Burali-Forti, Delbœuf,
Love, Russell.
- 1898. Cassani, Hilbert.
- 1900. Sommer (3), Veronese.
- 1901. Pieri (2).
- 1902. Halsted (7), Veblen.
- 1903. Mollerup, Peano, Russell,
Wilson (3).
- 1904. Halsted (3), Kagan (1),
Schor.
- 1905. Marletta (2), Royce, Sus-
lov, Vahlen, Wellstein.
- 1906. Schweitzer, Veblen (1),
Whitehead (2).
- 1907. Dingler, Enriques (2),
Hjelmslev (2).
- 1908. Pieri.
- 1909. Schweitzer (1, 3).
- 1910. Coolidge, Fano, Mollerup
(1), Rosenthal, White-
head (1).
- 1911. Auerbach.

FOUNDATIONS OF ELLIPTIC AND SPHERICAL GEOMETRY.

- 1892. Sikstel.
- 1902. Halsted (5).
- 1905. Dehn (1), Halsted (4),
Hessenberg (2, 3).
- 1910. Coolidge.

FOUNDATIONS OF HYPERBOLIC GEO- METRY.

- 1903. Hilbert (3).
- 1904. Liebmann, Schur.
- 1908. Liebmann.
- 1910. Coolidge.

FOUNDATIONS OF PROJECTIVE GEO- METRY.

- 1847. v. Staudt.
- 1856. v. Staudt.

- 1875. Clebsch.
- 1881. de Paolis.
- 1883. Aschieri.
- 1884. de Paolis.
- 1887. Pasch, Reyes y Prósper.
- 1894. Enriques (5).
- 1895. Fano (4), Pieri.
- 1896. Amodeo (1, 2), Pasch.
- 1897. Amodeo, Pieri (1, 3),
Scott.
- 1898. Dixon (1, 2), Enriques (1),
Zeuthen.
- 1901. Doehlemann.
- 1903. Hessenberg (1), Russell.
- 1904. Macaulay (1), Wilson.
- 1905. Amodeo, Pieri (2),
Richard, Vahlen, Well-
stein.
- 1907. Enriques (2).
- 1909. Kommerell.
- 1910. Guareschi (2), Veblen and
Young.

Axioms for line-geometry.

- 1901. Pieri (1).

Axioms for euclidean geometry of n dimensions.

- 1891. Amodeo (1), Veronese.
- 1892. Amodeo (1), Fano.
- 1896. Pieri.
- 1902. Blichfeldt (1).
- 1905. Pieri (1).
- 1906. Pieri.
- 1907. Mansion (1).
- 1909. Schweitzer (2).
- 1910. Owens.

SYSTEMS OF AXIOMS FOR METRICAL AND DESCRIPTIVE GEOMETRY.

- 1882. Pasch.
- 1889. Peano.
- 1894. Peano.
- 1899. Hilbert, Pieri.
- 1900. Padoa (1).
- 1901. Pieri (2).
- 1902. Kagan (1).
- 1903. Kagan (1).
- 1904. Levi, Veblen (2).
- 1905. Wellstein.
- 1907. Whitehead (1), Guarducci
(see Enriques 3 (4)).
- 1908. Moore.
- 1910. Coolidge, Levi.

SYSTEMS OF AXIOMS FOR PROJECTIVE GEOMETRY.

- 1896. Pieri.
- 1898. Pieri (1, 2).

1902. Moore (1).
 1904. Levi.
 1905. Rose.
 1906. Whitehead (1).
 1908. Veblen and Young.
 1910. Levi, Whitehead (1).

Dependence of plane projective upon
 metrical geometry.

1891. Schur.
 1901. Lechalas (2).
 1902. Mansion (1).
 1903. Lechalas, Lewyckij.

The fundamental theorem of projec-
 tive geometry.

1873. Klein.
 1874. Klein.
 1880. Darboux, Klein (1).
 1881. Schur.
 1897. Zeuthen (1-3).
 1898. Schur (1, 2).
 1901. Balser.
 1904. Pieri.
 1906. Whitehead (1).
 1908. Meyer.

Introduction of coordinates and ideal
 elements; the projective scale;
 quadrilateral construction.

1847. v. Staudt.
 1856. v. Staudt.
 1870. Fiedler.
 1873. Lüroth.
 1890. Klein (1).
 1891. Schur.
 1895. Burkhardt.
 1898. Enriques (2).
 1900. Bonola (1).
 1903. Bunickij.
 1904. Pexider.
 1906. Whitehead (1).
 1908. Hölder.
 1910. Guareschi (3), Owens.

Theorems of Pascal (or Pappus) and
 Desargues. (*Ref. Q1d.*)

1902. Hessenberg.
 1903. Hessenberg (2).
 1904. Hessenberg (1).
 1905. Hessenberg (1), Vahlen.
 1907. Levi (2), E. Meyer (4).

Idea of order.

1892. Vailati.
 1902. Halsted (2), Moore (2).
 1908. Hahn.

Axiom of Continuity (Archimedes).
 (*Ref. J5b, Q1d.*)

1872. Dedekind.
 1882. Stolz.
 1888. Dedekind.
 1890. Veronese.
 1891. Stolz, Veronese.
 1892. Veronese.
 1895. Killing.
 1897. Schoenflies, Veronese
 (1).
 1898. Strong, Veronese.
 1901. Kneser, Schur, Tirella.
 1902. Bonnel (2), Gremigni,
 Møllerup.
 1903. Geissler (1, 2), Levi,
 Schur.
 1904. Geissler (1, 2), Halsted
 (3), Kneser, Petronie-
 vics, Veblen (1).
 1905. Dehn (1), Halsted (1),
 Mansion (4), Wellstein.
 1906. Vahlen.
 1907. Combebiac, Enriques (2),
 Giudice, Vitali (*see*
 Enriques 3 (5)).
 1909. Giudice.

**Q1aα. The postulate of Euclid and the
 theory of parallels.**

Generalities.

1587. Patricio.
 1621. Savile.
 1693. Wallis (1).
 1733. Saccheri.
 1786. Lambert.
 1790. Kaestner.
 1794. Legendre.
 1796. Kaestner.
 1797. Playfair.
 1806. Gauss.
 1807. Hoffmann.
 1809. Playfair.
 1811. Leslie.
 1812. Playfair.
 1816. Gauss and Gerling (2).
 1818. Anon.
 1820. Gerling, Hauber.
 1824. Legendre.
 1829. Gauss and Bessel.
 1830. Thompson.
 1832. W. Bolyai.
 1833. Bürger, Legendre, Thomp-
 son.
 1834. De Morgan, Thompson.
 1835. Hill, Lobachevsky (2).
 1844. Newman.
 1850. Buniakovskij (2).

1860. Gauss and Schumacher.
 1863. Hoüel.
 1864. Kelland.
 1867. Hoüel.
 1870. Baltzer, Fleury (2),
 Hoüel (2), Marie.
 1871. Lamarle, Marie.
 1872. De Morgan, Saleta.
 1873. Genocchi, Purgotti, de
 Tilly.
 1874. Spitz.
 1875. Claudel.
 1876. Günther (1, 2).
 1877. Erdmann, Günther (4).
 1879. Kettner.
 1883. Dauge.
 1885. Dechamps, Galimberti.
 1888. Frasnighni.
 1889. Bonnel (1).
 1894. Palatini.
 1895. Crivetz, Dellac.
 1896. Sikstel (1).
 1898. Brassai, Hadamard (2).
 1899. Barbarin (2).
 1900. Bonola (2), Mansion (1),
 Tichomandrickij.
 1901. Frasnighni, Simon.
 1902. Bordage, Gérard (1),
 Hochmann, Laurent (1).
 1903. Baron, Brocard, Commo-
 let, Laudahn, Pailler,
 de Peslouan, Popovici,
 Richard.
 1904. Dombrowski, Fraunhofer,
 Hessenberg (3), Mich-
 aux, Vailati.
 1905. Fontené, Frankland,
 Sforza.
 1906. Geissler (1), Seleznev.
 1907. Enriques (2), Sittignani.
 1908. Nielsen, Richard, Rich-
 ert.
 1909. Mansion, Rousseau.
 1910. Young.

SUM OF THE ANGLES OF A POLYGON.

Angle-sum of a triangle. (*See also*
 Thibaut's proof, below.)

1733. Saccheri.
 1786. Lambert.
 1800. Legendre.
 1810. Knight.
 1812. Gergonne.
 1818. Hessling, Mayer.
 1823. Legendre.
 1825. Servois, Taurinus.
 1827. Young.
 1828. Terquem.
 1833. Legendre, Wiessner.
 1836. Bras.

1837. Bras, Corbon, Dresler,
 Wiessner.
 1844. Meikle.
 1852. Schultén (2).
 1860. Gauss and Schumacher.
 1864. Kelland.
 1865. Gicca, Anon.
 1869. Bertrand, Carton, Mina-
 relli.
 1870. Baltzer, Bertrand, Finck,
 Lebesgue, Lionnet.
 1874. Spitz.
 1883. Agolini, Petersen.
 1889. Suni.
 1890. Schüler.
 1893. Schüler, Anon. (3).
 1898. Dauge (2), de Tilly.
 1899. de Tilly (1, 2).
 1900. Dehn (1), Hoffmann.
 1905. Bonola (2), Sincov, Ticho-
 mandrickij (1).
 1908. Tichomandrickij.

Theorem of Pythagoras.

1897. Reyes y Prósper (3).
 Existence of a rectangle.
 1741. Clairaut.
 1808. Schweikart.
 1813. Duttenhofer.
 1817. Lüdicke.
 1856. Hennessy (2).
 1885. Stolz.
 1899. Collignon.

ASSUMPTION OF SIMILAR FIGURES.

1693. Wallis (2).
 1794. Legendre.
 1803. Carnot.
 1819. Maurice, Anon.
 1821. Creizenach.
 1824. Laplace.
 1827. Moebius.
 1839. Day.
 1851. Buniakovskij.
 1860. Delbœuf.
 1892. Renouvier.
 1893. Couturat (1, 2), Lechalas.
 1894. Delbœuf, Lechalas.
 1901. Wickersheimer.
 1903. Varisco.

DIRECTION ASSUMPTION.

1801. Schwab.
 1814. Schwab.
 1824. Jacobi.
 1838. Young.
 1844. Wedgwood.
 1851. Ueberweg.
 1856. Wedgwood.

- 1891. Dixon; Schmidt.
- 1892. Renouvier.
- 1904. Lagrange (2).
- 1905. Fabre.
- 1908. Hill.

Parallels make equal angles with a transversal.

- 1801. Gumaelius, Schwab.
- 1809. Thibaut (5th ed.).

— as definition. (r =right angles).

- 1655. Hobbes.
- 1658. r Borelli.
- 1731. Varignon.
- 1770. Bezout.
- 1790. Swinden.
- 1853. r Hennessy.
- 1856. r Stevelly (1, 2).

Parallels meet at infinity.

- 1604. Keppler (and Newton).
- 1639. Desargues.
- 1832. Steiner.

Two intersectors cannot both be parallel to the same straight line.

- 1560. Proclus.
- 1781. Hindenburg.
- 1785. Ludlam.
- 1797. Playfair.

Straight lines cannot converge and then diverge without crossing.

- 1594. Nasiraddin.
- 1715. Malézieu.
- 1734. Hausen.
- 1756. Simson.
- 1758. Karsten.
- 1760. Karsten.
- 1778. Karsten.
- 1780. Simpson.
- 1786. Bendavid, Karsten.
- 1792. Castillon.
- 1807. Hoffmann.
- 1819. Müller.
- 1823. Nordmann.
- 1859. Hoffmann.
- 1869. Genocchi (2).
- 1904. Dassen.
- 1905. Dassen, Hay.

DISTANCES.

The distance between two intersecting lines increases without limit.

- 4th cent. B.C. Aristotle (1).
- 1560. Proclus.

Distance between two parallels remains finite.

- 1560. Proclus.

Parallels are equidistant.

- 1st cent. B.C. Geminus.
- 1569. Ramus.
- 1574. Clavius.
- 1603. Cataldi.
- 1604. Cataldi, Oliver.
- 1615. Cataldi.
- 1641. Guldin.
- 1654. Tacquet.
- 1658. Borelli.
- 1680. Giordano.
- 1686. Giordano.
- 1747. Simpson.
- 1751. Hanke.
- 1752. Boscovich.
- 1759. d'Alembert.
- 1761. Hagen.
- 1770. Bezout.
- 1775. Bossut.
- 1803. Kircher.
- 1808. Ouvrier.
- 1810. Suzanne.
- 1815. Metternich.
- 1817. Borgen.
- 1819. Lüdicke, Müller.
- 1820. Lüdicke.
- 1822. Lüdicke, Metternich.
- 1834. Thomson.
- 1837. Gräf.
- 1853. Thompson.
- 1856. Thompson.
- 1859. Lambert.
- 1862. Thompson.
- 1866. Ryan.
- 1905. Bonola (1).
- 1906. Lemaire.
- 1908. Niewenglowski.

— as definition.

- 1st cent. B.C. Posidonius.
- 5th cent. Aganis.
- 1656. Hobbes.
- 1671. Pardies.
- 1700. de Chales.
- 1705. Scarburgh.
- 1710. Wolff.
- 1715. Wolff.
- 1741. La Caille.
- 1808. Schweikart.
- 1818. Bonnycastle.
- 1856. Hennessy (3).
- 1864. Laurent.
- 1868. Laurent.
- 1870. Fleury (2).
- 1878. Dietrich.

PROPERTIES OF INCIDENCE, &c.

A line can be drawn through a given point to cut both arms of an angle.

- 1739. Segner.
- 1791. Lorenz.
- 1800. Legendre.
- 1818. Hessling.
- 1819. Cresswell.
- 1833. Legendre.
- 1894. Cullovin.

An intersector of one parallel also meets the other.

- 1560. Proclus.
- 1758. Koenig.
- 1789. Bonycastle.
- 1823. Huber.
- 1891. Dixon.

Every point in one given line is the projection of some point in another given line.

- 1787. Franceschini.
- 1794. Legendre.
- 1798. Guriev.
- 1887. Budden.
- 1902. Gronau.

The backwards prolongations of two parallels are also parallel.

2nd cent. Ptolemy (2).

Three points not collinear are concyclic.

- 1786. Lambert.
- 1796. Legendre.
- 1823. Anon.
- 1832. W. Bolyai.
- 1906. Lippmann.

INFINITESIMALS AND INFINITIES.

Assumption of an element of length.

(Cf. V1d, Atomic geometry).

- 1789. Voigt.
- 1797. Langsdorf.
- 1802. Langsdorf.
- 1895. Bonnel.
- 1902. Bonnel (3).

Assumption of a last straight line to cut a given one.

- 1812. Gergonne.
- 1823. Paucker.
- 1826. Olivier.
- 1838. Young.
- 1851. Scorza.

1879. de Rossi Re.

1894. Cullovin.

1895. Crivetz, Cullovin.

Demonstrations based upon a consideration of infinite areas.

- 1667. Arnould.
- 1778. Bertrand.
- 1780. Schultz.
- 1784. Schultz.
- 1786. Eichler, Gensichen, Schultz.
- 1796. Anders.
- 1803. Lacroix.
- 1812. Bertrand.
- 1816. Bürger, Crelle.
- 1818. Hellwag, Hessling.
- 1820. Bürger.
- 1823. Legendre.
- 1824. Stein (and Gergonne).
- 1831. De Morgan.
- 1833. Bürger, Legendre.
- 1835. Crelle.
- 1838. Young.
- 1849. Schultén.
- 1860. Baltzer.
- 1871. Transon (1, 2).
- 1875. Becker.
- 1876. Johnson, Lüroth.
- 1877. Becker (2), Polster.
- 1878. Dietrich, Polster.
- 1887. Seeger.
- 1888. Newman.
- 1894. Reishaus.
- 1904. Lagrange (1), Sornein.

REPEATED CONSTRUCTIONS.

- 1794. Legendre.
- 1820. Struve.
- 1822. Müller.
- 1825. Servois.
- 1830. Thompson.
- 1833. Legendre.
- 1835. Nichol.
- 1850. Buniakovskij (1).
- 1869. Bertrand, Carton, Minarelli.
- 1870. Carton, Lionnet.

KINEMATICAL.

Thibaut's Proof of the angle-sum by successive rotations about the vertices of the triangle.

- 1797. Playfair (3rd ed.).
- 1802. Krause.
- 1809. Thibaut.
- 1850. Germar.
- 1856. Chasles, Vincent (1, 2).
- 1857. Martin.

1877. Günther (3).
 1882. Casey.
 1884. Geoghegan, Henrici.
 1904. Mackay.

Line moving at constant angle to another.

1693. Nasiraddin, Wallis (2).
 1758. Kaestner.
 1797. Schmidt.
 1803. Kircher.
 1813. Herrmann.

Other kinematical proofs.

1823. Paucker.
 1853. Thompson.
 1856. Thompson.
 1862. Thompson.
 1894. Cullovin.
 1895. Love.
 1903. Rabinovitch.

REPLIES TO ATTEMPTED PROOFS.

1816. Gauss (1).
 1824. Stein.
 1852. Schultén (1).
 1860. Gauss and Schumacher.
 1870. Baltzer, Breton.
 1879. Genocchi.
 1884. Henrici.
 1887. Henrici (*see* Budden).
 1895. Love.
 1896. Mansion (1).
 1897. Barbarin (1, 2), Mansion (4).
 1898. Barbarin (2), Mansion (1, 4).
 1902. Barbarin (3).
 1903. Tarry.
 1908. Sincov (*see* Tichoman-drickij).

MISCELLANEOUS ATTEMPTS TO PROVE
 EUCLID'S POSTULATE.

- 9th cent. Thabit.
 10th cent. Yuhanna.
 1613. Valerio.
 1642. Gestrin.
 1671. Guarini.
 1744. Strömer.
 1746. La Chapelle.
 1747. Segner.
 1750. Camus.
 1752. Kraft.
 1753. Kraft, Sauveur.
 1770. Scherffer.
 1771. Boehm.
 1772. Luino.
 1778. Kesaer.

1780. Hauser.
 1781. Austin, Felkel.
 1783. Pagnini.
 1784. Venturi.
 1786. Hofmann, Pfeiderer.
 1788. Schübler.
 1789. Lindquist.
 1790. Cagnazzi, Schöttering, Schultz.
 1791. Voigt.
 1792. Ebert.
 1793. Hauff.
 1794. Pagnini.
 1795. Chauvelot, Rehbein, Saladini, Wildt.
 1797. Pfeiderer.
 1798. Gilbert.
 1799. Hauff, Hindenburg, Anon.
 1800. Wildt.
 1801. Hoffmann, Limrick.
 1802. Chauvelot.
 1803. Hauff, Ide.
 1804. W. Bolyai, Bolzano, Jacques.
 1805. Lacroix.
 1806. de Gelder.
 1807. Hauff, Scheibel.
 1808. Abreu, Jeuffrain, Schwab.
 1809. Abreu.
 1810. de Gelder.
 1811. Brunacci, Le Carpentier, Neubig.
 1812. Bois-Bertrand, Gergonne, Legendre.
 1815. Guntz, Kjellin, Metternich.
 1816. Develey, Hoffmann, Lüdicke, Vermehren.
 1817. Blum, Ohm, Wachter.
 1818. Exley, Flauti.
 1819. Hauff, König, Ohm.
 1820. Gröson.
 1821. Erb, Hauff, Küster, Mönich, Anon.
 1822. Fries, Ivory, Meikle.
 1823. Paucker.
 1824. Bensemann, Foex, Ivory, Walsh.
 1825. Colburn, Hegenberg.
 1826. Bouvier, Colburn, Grashof, Hoffmann, Minarelli, Müller, Olivier, Strong.
 1827. Bresztyenszky, de Gelder, Knar, Koch, Neubig.
 1828. Knar, Lampredi, Scorza.
 1829. Courtin, Lehmann, Reinhold.
 1830. Rindfleisch, R...r, Sokolowski, Thompson.

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| 1831. Falck, Lehmann. | 1869. Fleury, Twining. |
| 1832. Doppler, Giroud, Wilkie. | 1870. Boillot, Dillner, Fleury |
| 1833. Ekstrand, Thompson,
Wiessner. | (1), Fuix (1, 2), Goubet,
Marchand, Sainte-Croix
(1, 2), de Tilly (2). |
| 1834. Ampère, Bürger, Dresler,
Metzing, Tisserand. | 1872. Buniakovskij (1, 2),
Cipolla, Germann, Sme-
tacek, Twining. |
| 1835. Bürger, Dantas-Pereira,
de Gelder, Nichol,
Schröder. | 1874. Leinemann, Rossetti. |
| 1836. Gaudain, Hennig, Kaiser,
Lampredi, Lemonnier,
van Tenac. | 1875. Bonnin, Falk. |
| 1837. Horn, Wiessner. | 1876. Eisenmenger, Günther
(1). |
| 1838. Bazaine, Cateau, Durand,
Lemonnier. | 1878. Conti. |
| 1839. Amiot, Guimbertaud,
Märcker. | 1879. Duda, Fleury, Ruffolo. |
| 1840. Bischof, Haüy, Mühl-
hofer, Ruello, Seeber,
Thompson. | 1881. Sibirakov. |
| 1841. Amiot, Fusco, Lyncker. | 1882. Wilmert. |
| 1842. Claudel, Frémont, Le
Villain, Marchand,
Marin, Powell, Prince-
Smith. | 1883. Agolini, Beyda, Fleury,
Strona. |
| 1843. Paillet. | 1884. Luvini. |
| 1844. Cournot. | 1885. Korneck. |
| 1845. Acostas, Broc, Lafitte. | 1886. Ragache. |
| 1846. Matzka, Schultz, Twining. | 1887. Sibirakov, Wilson. |
| 1847. Dudeck, Lefrançois,
Marsano, Meikle. | 1888. Dodgson, Duchemin (1,
2), Lissenco. |
| 1848. Christian, Sirban, Wiess-
ner. | 1889. Duchemin, Gros-Désor-
meaux, Sbrana, Tucker. |
| 1849. Knorr, Rivaud. | 1890. Sachs. |
| 1850. Buniakovskij (1, 2),
Hill. | 1893. Salamitto, Sarrieu. |
| 1851. Buniakovskij, Reuschle,
Scorza. | 1894. Dressler, Jubinal. |
| 1852. Buijs Ballot, Hörlych,
Martynovsky, Schultén
(1, 2), Spach. | 1895. Frolov. |
| 1853. Buniakovskij, Dobelly,
Kregcz. | 1896. Frolov (1, 2). |
| 1854. Krüger, Schultz. | 1897. Frolov, Wickersheimer. |
| 1855. Cabot, Sippel. | 1898. Frolov (1, 2), Tarry. |
| 1856. Granlund, Hennessy,
Osorio, Stevelly, Young | 1899. Frolov (1, 2). |
| 1857. Day, Lamarle, Nichol. | 1900. Bosworth, Vidal. |
| 1858. Beck, Bouché, Krüger,
Rozet. | 1901. Gelin, Pierantoni. |
| 1860. Kulik. | 1902. Gronau, Smith, Wickers-
heimer. |
| 1861. Collignon. | 1903. Cadenat, Pflaum. |
| 1862. Belenay, Lotz, Thier-
mann. | 1904. Pondichy, Raganti. |
| 1863. Buniakovskij. | 1905. Liasse (1, 2), Ryan. |
| 1864. Boillot. | 1906. Bourlet, Paillet. |
| 1866. Rérolle (1, 2). | 1907. Bourlet, Gérard. |
| 1867. L. Giacomini, Murray,
Witte. | 1908. Galperin, Sabinin. |
| 1868. Agolini. | 1910. Martinez. |

Q1a8. Curvature of space. (For geometry on surfaces of constant curvature *see* Q1eγ. For surfaces of constant curvature in non-euclidean space *see* Q1 (O6g), and in particular for surfaces of zero curvature *see* Q1 (K16a, L²2.) For questions on differential geometry of S_n, not specially in relation to the foundations of geometry *see* C²2, and for transformation of the quadratic differential form *see* C4d.)

General investigation of curved surfaces relevant to non-euclidean geometry, *i.e.* measure of curvature, geodesics, &c.

- 1825. Gauss.
- 1827. Gauss.
- 1828. Gauss.
- 1838. Minding (1, 2).
- 1839. Minding.
- 1840. Minding.
- 1850. Liouville.
- 1857. Codazzi.
- 1876. Hoppe.
- 1887. Darboux.
- 1894. Bianchi.
- 1896. Bianchi (1), Sabinin.
- 1900. Liebmann (1, 2).
- 1901. Hilbert (2), Liebmann (1, 2, 4), Anon. (2).
- 1902. Holmgren.
- 1903. v. Lilienthal.

Space of constant curvature. (*Ref.* **Q2.**)

- 1881. Donadt.
- 1885. Brill.
- 1899. Liebmann (1), Tedone.

Space of zero curvature.

- 1889. Ricci.
- 1895. Banal.
- 1896. Banal.
- 1897. Banal.
- 1904. Mercatanti.

"Curved" space. (*Ref.* **Q1.**)

- 1873. Ingleby.
- 1876. Tait.
- 1877. Günther (2), Newcomb.
- 1878. Grassmann, Newcomb (2).
- 1881. Donadt.
- 1885. Clifford.
- 1891. Cranz, Dixon.
- 1893. Newcomb.
- 1896. Lechallas (1, 2).
- 1901. Crawley, Knibbs (1).

Determination of the space-constant ("curvature") by measuring stellar parallax.

- 1829. Lobachevsky.
- 1855. Lobachevsky.
- 1891. Cranz, Peirce.
- 1897. Novikov.
- 1900. Barbarin (1), Schwarzschild.
- 1908. Harzer.

DIFFERENTIAL BASIS FOR GEOMETRY, STARTING WITH THE LINE-ELEMENT. (*Ref.* **Q4d.** For application of continuous groups and calculus of variations to the same question *see* **Q1a7.**)

- 1861. *n* Riemann.
- 1866. *n* Riemann.
- 1881. Donadt.
- 1883. Ball (1).
- 1886. *n* Schur (1).
- 1890. Picard.
- 1894. Cesàro (1).
- 1902. Bianchi (1), Woods.
- 1904. Cesàro (1, 2).
- 1905. Cesàro, Schlesinger (2).
- 1908. Darboux.
- 1910. Coolidge.

Q1a7. INVESTIGATION OF THE LINE-ELEMENT BY VARIOUS METHODS. (For differential method *see* **Q1a8.**)

EXAMINATION OF THE RELATIONS CONNECTING THE FINITE DISTANCES OF FIVE OR MORE POINTS IN SPACE. (*Cf.* **Q1 (K1b).**)

- 1773. Lagrange.
- 1806. Carnot.
- 1868. Helmholtz.
- 1871. d'Ovidio.
- 1883. Ball (1).
- 1891. Rouché.
- 1893. Goedseels, de Tilly.
- 1904. Lechallas (1).
- 1906. de Donder.
- 1907. de Donder, Enriques (2).
- 1908. Mansion (2).

INVESTIGATION OF THE LINE-ELEMENT BY CALCULUS OF VARIATIONS.

- 1906. Stromquist.
- 1907. Study.

APPLICATION OF CONTINUOUS GROUPS. (*Ref.* **J4f.**)

- 1868. Helmholtz.
- 1872. Klein (1).
- 1875. Clebsch.
- 1883. Ball (1).
- 1886. Lie.
- 1888. Lie.
- 1890. Lie (1).
- 1892. Killing, Lie (2, 3), Picard.
- 1893. Killing (2), Klein (1).
- 1894. Love (1).
- 1895. Halsted (4).
- 1897. Klein (2), Newson.
- 1898. Halsted (2), Poincaré (1).

- 1899. Duport.
- 1900. Lovett (1).
- 1901. Bonola, *n* Lovett (1, 2).
- 1902. Hilbert (2).
- 1905. Combebiac (1).
- 1907. Enriques (2).
- 1909. *n* Brouwer (3).
- 1910. Heffter.

Q1b. Hyperbolic geometry (Lobach-evsky-Bolyai). (For special topics *see* **Q1**. N.B.—When the reference symbol **Q1b** is followed by a further symbol within brackets, **Q1** is always to be referred to.)

General. (For generalities relating to non-euclidean geometry, not specially hyperbolic, *see* **Q1**.)

- 1823. J. Bolyai.
- 1824. Gauss and Taurinus.
- 1825. Taurinus.
- 1851. W. Bolyai, Gerling.
- 1860. Gauss and Schumacher.
- 1867. Baltzer, Forti.
- 1872. Buniakovskij (2).
- 1873. Hoffmann.
- 1876. Peressini.
- 1881. Suvorov.
- 1885. Thue (1, 2).
- 1888. Beckmann.
- 1894. Šiškin.
- 1895. Archimovič, Isely.
- 1899. Frolov (3).
- 1900. Woods.
- 1901. Halsted (5).
- 1902. Stäckel (2).
- 1903. Réthy, Stäckel (2).
- 1906. Hayashi.

General elementary development.
(*See also* **Q1 (K)**.)

- 1733. Saccheri.
- 1786. Lambert.
- 1816. Wachter.
- 1818. Schweikart.
- 1820. Schweikart.
- 1826. Taurinus.
- 1860. Young.
- 1882. Clifford (1).
- 1900. Gauss.
- 1903. Beke.

Hyperbolic functions and trigonometry.

- 1759. de Foncenex.
- 1870. Grunert.
- 1881. Günther.
- 1884. Mansion.
- 1903. Mansion (2).

Q1c. Spherical and elliptic geometry (Riemann-Klein). (For special topics *see* **Q1**. N.B.—When the reference symbol **Q1c** is followed by a further symbol within brackets, **Q1** is always to be referred to.)

General. (For generalities relating to non-euclidean geometry, not specially elliptic, *see* **Q1**.)

- 1733. Saccheri.
- 1764. Reid.
- 1786. Lambert.
- 1866. Riemann.
- 1873. Clifford.
- 1878. Killing.
- 1884. Henrici.
- 1885. Halsted.
- 1892. Halsted (2).
- 1894. Mansion (1, 2).
- 1895. Mansion (1, 2).
- 1904. Bordage, Coolidge (2).
- 1905. Halsted (4).

ELLIPTIC GEOMETRY (polar or single form, as opposed to spherical geometry = antipodal or double form, of elliptic geometry.)

- 1871. Klein.
- 1876. Frankland (Monro, Hogen, Skey), Klein.
- 1877. Monro, Newcomb.
- 1878. Killing.
- 1883. Ball (1).
- 1890. Klein (1).
- 1891. Killing.
- 1892. Halsted (1).
- 1899. Mannoury (1).
- 1902. Combebiac, Gérard (2), Anon. (4).
- 1903. Mansion (3).
- 1904. Coolidge (2).

(For distinction between elliptic or spherical geometry and the geometry upon a sphere *see* **Q1**.)

Q1d. VARIOUS GEOMETRIES. (For hyperbolic geometry *see* **Q1b**; for elliptic geometry *see* **Q1c**; for the Cayley-Klein projective metric *see* **Q1ea**.)

Non-archimedian geometry.

- 1891. Veronese.
- 1899. Hilbert.
- 1900. Dehn (1).
- 1902. Bindoni.
- 1904. Geissler (1).
- 1905. Mansion (4), Veronese.
- 1906. Enriques, Schoenflies (1).

1907. Enriques (2), Hahn, Vitali (*see* Enriques 3 (5)).
1908. Veronese.
- Non-desarguesian geometry.
1899. Hilbert.
1901. Lechallas (2).
1902. Moulton.
1905. Vahlen.
1907. Veblen and MacLagan-Wedderburn (2).
- Non-pascalian geometry.
1899. Hilbert.
1904. Hessenberg (1).
1907. Veblen and MacLagan-Wedderburn (2).
- Non-pythagorean geometry.
1903. Hilbert (2).
- Finite projective geometries.
1892. Fano.
1898. Pieri (1).
1904. Petronievics, Veblen (2).
1905. MacLagan-Wedderburn.
1906. Veblen (1), Veblen and Bussey (2), Whitehead (1).
1907. Levi (1), MacInnes, Sommerville (1), Veblen (1, 2).
1908. Coble.
1910. Conwell.
- Semi-euclidean geometry in which the angle-sum = $2R$.
1900. Dehn (1).
1903. Møllerup.
1905. Bonola (2).
1907. R. L. Moore.
- Geometry in which $c^2 = a^2 - l^2$.
1897. Hinton.
1904. Hinton (2), Mercatanti.
- Geometries with absolute of special form.
1892. Busche.
1910. Sommerville ($n1, 2$).
- Geometry in which the absolute consists of the two double quadrics of the general linear dualistic correlation.
1892. n Fontené.
1898. Fontené.
1904. Fontené.
1907. E. Meyer (2).
- Periodic geometry (not elliptic).
1897. Hadamard (1).
- Quadratic (discontinuous) space.
1898. Strong.
1908. Moore.
- Various discrete geometries.
1904. Petronievics, Veblen (2).
1905. Petronievics.
1907. Petronievics.
- Geometry of a Lattice (Punkt-Gitter).
1896. Klein (2), n Minkowski, n Weber.
1904. Minkowski.
1907. Enriques (2), n Minkowski.
1910. Hilbert.
- Geometries in which the straight line is the shortest. (*Ref.* Q1ea.)
1901. Hamel.
1903. Hamel.
1906. Bliss.
- Geometries in which circles are the shortest. (*Ref.* Q1eβ.)
1906. Stromquist.
- Various geometries.
1904. Veblen (2).
- Q1e. CONCRETE REPRESENTATIONS OF NON-EUCLIDEAN GEOMETRY.**
- Q1ea. BY STRAIGHT LINES AND PLANES WITH THE CAYLEY-KLEIN PROJECTIVE METRIC.**
- Projective metric; theory of the absolute. (For special theorems in non-euclidean geometry *see* Q1.)
1853. Laguerre.
1859. Cayley.
1865. Clifford.
1869. Clifford.
1871. Cayley, Klein.
1872. Beltrami (1, 2), Cayley, Klein (1, 5).
1873. Clifford, Klein, Lindemann, d'Ovidio (1, 2), Stahl.
1874. Battaglini (1-4).
1875. Clebsch, d'Ovidio (1, 2).
1876. Battaglini, Cremona, d'Ovidio (1-4).
1877. d'Ovidio (1).

1878. Clifford.
 1879. Ball.
 1881. Aschieri, d'Ovidio, Story.
 1882. Koenigs, Ricordi, Story
 (1, 2).
 1883. Ball (1), Klein.
 1885. Hossfeld.
 1887. Poincaré.
 1888. Tirelli.
 1889. Ball.
 1890. Cayley (1, 2), Klein (1).
 1891. d'Ovidio (1-3), Schilling.
 1893. Johnson, d'Ovidio (1).
 1894. Scott, Wirtinger.
 1896. Guichard (1), Halsted (5),
 Nekrasov, Study.
 1897. Klein and Fricke (1),
 Scott, Thomae.
 1898. *n* Barbarin (1), Fiedler,
 F. S. Macaulay.
 1899. Fontené (1).
 1900. Kölmel, Morrice.
 1901. Study.
 1902. Palmieri, Study (1).
 1903. Cotton, Study.
 1904. Palmieri.
 1906. Berkhan, Sommerville
 (2).
 1907. Combebiac (2), Enriques
 (2), Hostinsky.
 1908. Combebiac (1).
 1910. Coolidge, Sommerville
 (*n* 1, 2).

Representation of surfaces of constant curvature on the plane.

1865. Beltrami.
 1868. Beltrami (1, *n* 2).
 1872. *n* Beltrami (1).
 1874. Escherich.
 1890. Padoa.
 1902. *n* Enriques (1), Zühlke.

Q1eβ. REPRESENTATION BY CIRCLES AND SPHERES CUTTING A FIXED SPHERE ORTHOGONALLY. (Conform representation.) (*See also* Q1, Application to function-theory.)

1888. Marcolongo.
 1891. Poincaré.
 1893. Klein (1), Suslov.
 1895. Lachtin.
 1903. Varicak.
 1905. Hessenberg (2), Liebmann (1), Wellstein.
 1906. Lony, Stromquist.
 1907. Magener, C. L. E. Moore.
 1910. Carslaw (1), Sommerville (3).

Other conform representations.

1896. Busse (1, 2).

Q1eγ. REPRESENTATION BY GEODESICS ON A SURFACE OF CONSTANT CURVATURE. (For distinction between non-euclidean geometry and geometry upon a surface of constant curvature *see* Q1.)

1868. Beltrami (1).
 1871. Klein.
 1872. *n* Beltrami (1).
 1873. Klein.
 1888. Beez.
 1891. Dixon.
 1901. Kommerell.
 1902. Zühlke.
 1908. Chandrikov.

Geometry on surfaces of constant curvature, + or -.

1839. Minding.
 1840. Minding.
 1857. Codazzi.
 1868. Christoffel.
 1869. Beltrami (1).
 1874. v. Escherich.
 1875. Clebsch.
 1876. Hoppe.
 1879. Hatzidakis.
 1881. Nebelung.
 1882. Voss.
 1886. Bianchi.
 1889. Bianchi, - Reina.
 1894. Bianchi.
 1895. Calinon, - Kagan (3).
 1897. - Hadamard (3).
 1898. Beliankin, Carda, - Hadamard (1), Schlesinger.
 1900. Sabinin.
 1901. - Király.
 1902. Thue.

The pseudosphere or surface of revolution of the tractrix.

1872. Beltrami (3, 4).
 1873. Genocchi, de Tilly.
 1884. Cayley.
 1898. Metzler.

Q1eδ. VARIOUS REPRESENTATIONS.

Binary forms.

1862. Fiedler.
 1866. Battaglini.
 1872. Klein (1).
 1882. Stéphanos.

Central projection of a sphere.
(*Ref. Q1ea*, and *V1d*, Physiological space.)

1892. M'Clintock.
1893. Johnson.

Orthogonal projection of a sphere.

1891. Poincaré.
1905. Mansion (2).

Conics in a plane.

1885. Study (1, 2).
1910. Emmerville (*see* 3).

Diametral sections of a quadric surface.

1887. Poincaré.
1909. Jansen.

Various representations.

1872. König.
1885. Porchiesi.
1893. Suslov.
1901. Petersen (2).
1905. Schor.

**Q2. SPACE OF n DIMENSIONS;
GENERALITIES, REPRESENTATIONS
AND APPLICATIONS.**
(For special topics consult the Index.)

1869. Sylvester.
1883. Cayley.
1885. Schendel.
1886. Gibbs, Peddie.
1898. Schiaparelli.
1900. Couturat (1).
1901. Knibbs (2).
1903. Haldane.

Q2a. GENERALITIES.

1746. Kant.
1844. Grassmann.
1866. Riemann.
1870. Cayley (1).
1872. Klein (1).
1876. Mansion, Tannery.
1877. Halsted, Hugo, Kaiser,
Kennon.
1878. Gilles, Grassmann, Spot-
tiswoode.
1879. Dreher.
1880. Halsted.
1884. Fullerton, Hinton,
Rhenius.
1886. Hinton.
1888. Caporali, G. D. H., Hin-
ton, Schlegel, Schofield.
1889. Lechalas.
1890. Badoureau, Haft.

1891. Cranz, Dixon, Segre (1),
Simon (1), Veronese.
1892. W. W. R. Ball, Preble,
Sanford, Wake.
1893. Klein (1), Mansion (1, 2),
Newcomb, Schubert.
1894. Enriques (1), Philippov,
Roberto.
1895. Farjon, Isely.
1896. de Galdeano, Hyslop.
1897. Dupuis, Servant, Story.
1898. Keyser, Newcomb, Pick.
1899. de Galdeano.
1901. Crawley, Kapteijn,
Lechalas (3), Lovett (1).
1902. Williams.
1903. Boucher (2), O. Simon.
1904. Hinton (1, 2), Lechalas
(3), E. Müller.
1906. Blum, Hiessl, Keyser,
Laurent (2), Phin.
1907. Fano (2), Loria (2).
1908. Bostwick, Carus (3),
Jacoby, Johnston, War-
rain.
1910. Manning.

Space of ∞ dimensions. (*Ref. J5b.*)

1896. Pincherle (1).
1898. Pincherle (1, 2).
1899. Cazzaniga.
1901. Pincherle and Amaldi.
1905. Fréchet.
1906. Fréchet.
1908. Fréchet.
1909. Hjelmslev.
1910. Fréchet (2).

Time of two or more dimensions.

1890. Calinon.
1892. Halsted (1).

“The realm of spirits.”

1679. More.
1878. Nichols, Tait, Wirth,
Zöllner (1, 2), Anon.
1879. Michaelis, Zöllner.
1880. Richter, Zöllner (1, 2).
1883. Nyström.
1884. Simony.
1885. Cumberland.
1890. Cranz.
1891. Cranz.
1892. Carpenter.
1897. Podmore.
1901. Schrey v. Kalgan.
1902. Podmore.
1907. Campbell.

References in fiction.

- 1884. Abbott.
- 1895. Wells (1-3).
- 1897. Wells (1, 2).
- 1901. Sommerville.
- 1903. Wells.
- 1904. Busch, Sommerville.
- 1906. Griffith.
- 1907. Hinton.

Q2b. REPRESENTATIONS OF SPACE OF n DIMENSIONS.By families of geometrical figures.
(*Ref. Q2ca.*)

- 1875. Spottiswoode (1, 2).
- 1892. Zindler.
- 1900. Vaes.

By weights, density, shading, &c.

- 1879. Lewis.
- 1880. Scheffler.
- 1891. Dixon.
- 1895. Nicoli.

Time as the fourth dimension.

- 1813. Lagrange.
- 1873. Dühring.
- 1885. S.
- 1895. Wells (1).
- 1904. Mehmke.
- 1909. Minkowski.
- 1910. Abraham.

Attempts to realise space of higher dimensions.

- 1873. Rodwell.
- 1884. Abbott.
- 1886. Hinton.
- 1888. Hinton, Schofield.
- 1892. Hall, Sanford.
- 1904. Hinton (2).

Q2c. Applications of n dimensions.**Q2ca. GEOMETRICAL APPLICATIONS.**

- 1888. Murer (1, 2).
- 1895. Palatini (1).
- 1905. Segre (1).
- 1910. Schoute (2), Smith.

DEDUCTION OF PROPERTIES OF ORDINARY SPACE by projection and section.

- 1827. Moebius.
- 1884. Segre (1), Veronese (3).
- 1886. Bordiga (5).
- 1887. Aschieri, Bordiga.
- 1888. Segre (4).

- 1893. Nicoli.
- 1895. La Rive (1).
- 1896. Ascione.
- 1897. Cosserat.
- 1901. Escott, Perazzo.
- 1902. Marletta (2).
- 1903. Schoute (4).
- 1904. Baker.
- 1905. Marletta (1).
- 1906. Hutchinson.
- 1908. Richmond.
- 1909. Snyder (1, 2).

Application to obtain orthogonal systems.

- 1877. Mehler.
- 1893. Puchta.
- 1905. Guichard (1).

Application to enumerative geometry.

- 1878. Cayley.
- 1886. Burali-Forti.
- 1898. Keyser.

REPRESENTATION OF GEOMETRICAL FIGURES BY POINTS IN S_n .

Applications to line-geometry.

- 1872. Klein (1-4), Lie (2).
- 1876. Cremona.
- 1882. Koenigs.
- 1883. Segre.
- 1884. Segre (6).
- 1885. de Paolis (1), Segre (1).
- 1886. Aschieri (3).
- 1888. Chizzoni.
- 1889. Loria (3).
- 1890. Busche, Pannelli, Pieri (2), Schumacher.
- 1892. Zindler.
- 1893. Del Re (1, 2), Fano, Klein (1), Koenigs.
- 1896. Fano (1), Loewy.
- 1897. Grace.
- 1898. Guichard (1-4), Veneroni.
- 1900. Palatini (2).
- 1901. Fano.
- 1902. Grace, Joly, Zindler.
- 1903. Aschieri, Jessop.
- 1905. Fano, Guichard (3), Hudson, Marletta (1).
- 1907. E. Meyer (1).
- 1909. Perazzo.

Systems of spheres.

- 1872. Lie (2).
- 1883. Segre.
- 1886. Aschieri (2, 3).
- 1892. Müller.

1893. Klein (1), Koenigs.
 1896. Loewy.
 1897. Grace.
 1898. Müller.
 1899. Del Re, Giacomini (2),
 Le Vavasseur (1).
 1900. Reye.
 1905. Keyser.
 1907. Lazzarini, E. Meyer (1).

Systems of conics. (*Ref. M⁷⁴, Sur-
 face of Veronese.*)

1868. Cayley.
 1885. Segre (1), Study (1).
 1892. Study (1, 2).
 1893. Aleksejev.
 1899. Gerbaldi.

Systems of spherical triangles.

1895. Chisholm [Young].
 1899. Chisholm Young.

Systems of congruent figures.

1900. Petersen.
 1901. Petersen (2).

Systems of points.

1891. Segre (2).
 1898. Palatini (2).
 1903. Severi (3).
 1905. Müller.

Q2c β . ANALYTICAL APPLICATIONS.

1834. Jacobi.
 1851. Sylvester.
 1854. Cayley.
 1859. Sylvester.
 1861. Riemann.
 1886. Brunel.
 1888. Bettazzi.
 1889. Stieltjes.
 1892. Czuber.
 1893. Stäckel.
 1897. Autonne (1, 2), Lachtin.
 1898. Meyer.
 1904. Tanturri.
 1905. Segre (1).

SYSTEMS OF EQUATIONS.

1847. Cauchy.
 1866. Salmon.
 1875. Cayley (1).
 1890. Nicoli.
 1893. Nicoli.
 1899. Griend.
 1903. Blumenthal (2).
 1904. Mehmke.

COEFFICIENTS OF AN EQUATION AS
 COORDINATES.

1868. Cayley.
 1886. Burali-Forti.
 1887. Klein.
 1889. Faerber.
 1892. Klein (2).
 1904. Schoute (6).
 1907. Carathéodory.

THEORY OF NUMBERS.

1896. Minkowski (1, 2), Weber.
 1898. Stouff.
 1902. Störmer.
 1907. Minkowski.

— Forms.

1887. Puchta.
 1891. Minkowski.
 1906. Minkowski.
 1908. Voronoj.

ALGEBRAIC FORMS.

1854. Cayley.
 1869. Noether (2).
 1882. Meyer (1-5).
 1884. Lindemann.
 1886. Voss.
 1889. Study (1).
 1891. J. Deruyts.
 1892. J. Deruyts, Waelsch.
 1893. Bianchi (2), Hilbert,
 Netto.
 1894. Czuber.
 1895. Waelsch.
 1896. Lindemann, Loewy, Voss.
 1897. Hurwitz, Kantor (1),
 Kohn, Study, Waelsch.
 1899. Autonne, Schoute (2).
 1900. Kantor (1).
 1901. Waelsch.
 1902. Kühne, Severi (2).
 1903. König, Palatini (2, 3).
 1905. Coble.
 1906. Giambelli (2), Medici,
 Severi (1, 2), Torelli,
 Wölffing.
 1907. Reichel.
 1909. Coble.
 1910. Waelsch.

COMBINATORIAL ANALYSIS.

1883. Veronese.
 1901. Piccilli (1).
 1902. Carp.
 1908. Barrau (4).

PROBABILITY AND STATISTICS.

- 1894. Czuber.
- 1899. Berry.
- 1901. Pearson (1, 2).
- 1903. Kirchberger.
- 1908. Elderton.

DIFFERENTIAL EQUATIONS.

- 1872. Lie (1, 2).
- 1873. Cayley (1).
- 1884. Schapira.
- 1885. Lie.
- 1886. Ricci.
- 1889. Engel.
- 1891. Lie.
- 1892. Borel, Waelsch.
- 1895. Fano (1, 2).
- 1896. Beudon, Dixon, Metzler.
- 1897. Beudon (1, 2).
- 1899. Fano (1, 2), Kowalewski (2), Lovett (2).
- 1900. Brill, Fano, Hadamard, Painlevé, Weber (1-3).
- 1901. Cartan (1, 2), de Donder, Kowalewski, Weber.
- 1903. Campbell, Kantor (2).
- 1904. Bianchi (3).
- 1905. Engel, Goursat.
- 1906. Steingraber, Wilson.
- 1907. Scrosoppi, Segre (2).
- 1908. Popovici, Werner.
- 1909. Darboux (1), Wright.

GROUP-THEORY. (*Ref. J4e, f.*)

- 1872. Lie (1).
- 1885. Lie.
- 1886. Engel, Killing.
- 1887. Engel.
- 1888. Killing.
- 1889. Study (2).
- 1890. Killing, Lie (2).
- 1892. Engel.
- 1893. Engel, Enriques (2, 3), Lie.
- 1894. Engel.
- 1895. Lie (1, 2).
- 1896. Fano (2-4), Wiman.
- 1897. Fano (2), Study.
- 1898. Fano (1, 2).
- 1900. Blichfeldt, Davissøn.
- 1902. Amaldi (2), Burnside, Lie.
- 1903. Campbell, Kantor (1, 2), Kowalewski.
- 1904. Kratzi, Vessiot.
- 1905. Amaldi (1).
- 1906. Apfelstedt, Wright, Kasner,
- 1909. Brouwer (4).

FUNCTION-THEORY.

Complex variables in S_n .

- 1889. Volterra (1-5).
- 1890. Fabri.
- 1893. Fabri.

Functions of many complex variables.

- 1892. Segre (2).
- 1900. Baker.
- 1901. Alezais.
- 1903. Blumenthal (1).
- 1904. Blumenthal (1, 2), Fubini (5).
- 1905. Hurwitz, Levi-Civita.
- 1906. Study (2).
- 1909. Amoroso (1, 2).

Representation of complex variables.

- 1891. Palatini.
- 1892. Segre (2).
- 1893. Del Pezzo (4).
- 1899. Giudice, Mannoury (2).
- 1901. Alezais, Autonne.
- 1905. Kommerell, Levi-Civita, Philipps.
- 1907. Poincaré (1).

Quaternions. (*See B12d.*)

Riemann surfaces.

- 1892. Del Pezzo, Hurwitz, Klein (1).
- 1905. Kommerell.
- 1909. M'Mahon.

Elliptic and hyperelliptic functions. (*Ref. M4b.*)

- 1880. Bianchi, Klein (2).
- 1884. Klein.
- 1885. Klein.
- 1886. Klein.
- 1890. Klein (2), Wirtinger.
- 1892. Hurwitz, Lie (1).
- 1895. Poincaré (3), Wirtinger.
- 1896. Lie.
- 1897. Lie.
- 1898. Picard, Poincaré (2).
- 1901. Dixon, Poincaré (3).
- 1906. Castelnuovo and Enriques.

Q2cy. PHYSICAL, &c., APPLICATIONS.

- 1879. Lewis.
- 1900. Carslaw.
- 1902. Joly.

Applications of hyperspace to explain physical phenomena.

- 1870. Clifford.
- 1872. Zöllner.
- 1876. Stumpf, Tait, Zöllner.
- 1878. Günther, Newcomb (2).
- 1882. Bresch.
- 1885. Clifford, Tait.
- 1891. W. W. R. Ball, Pearson.
- 1892. W. W. R. Ball, Pearson.
- 1899. Julius.
- 1902. Hinton.
- 1904. Hinton (1, 2).
- 1909. Minkowski.
- 1911. Wien (*see* Auerbach).

Application to dynamics.

- 1891. Stäckel.
- 1893. Painlevé, Stäckel (3), Staude.
- 1894. Hertz, Painlevé, Turksma.
- 1897. Hadamard (4), Stäckel (2).
- 1901. Malipiero.
- 1902. Lorentz.
- 1903. Fubini (3, 5).
- 1906. Levi-Civita.
- 1910. Bateman.

Graphical mechanics.

- 1904. Mehmke.

Geometrical optics.

- 1900. Lovett (4).
- 1908. Bateman.
- 1909. Bateman.

Chemistry.

- 1882. Bresch.
- 1904. Mehmke.

Q2cδ. MISCELLANEOUS APPLICATIONS.

Logic.

- 1890. Kempe, Nagy (1, 2).
- 1898. Dumont.
- 1904. Hinton (2).

Ethics.

- 1904. Nekrasov.
- 1905. Gopius.

Q3. Analysis situs.

- 1895. Poincaré (1).
- 1897. Mannoury, Servant.
- 1899. Poincaré (1).
- 1900. Poincaré (1).
- 1901. Poincaré (1, 2).
- 1902. Poincaré (1, 2).
- 1903. Stäckel (1, 2).

- 1904. Poincaré (2), Schoenflies, Wernicke.
- 1907. Dehn and Heegaard.
- 1908. Steinitz, Tietze.
- 1910. Dehn.

Knots in S_n .

- 1876. Klein.
- 1878. Tait, Zöllner (1, 2).
- 1879. Hoppe (2), Zöllner.
- 1880. Durège, Hoppe (2), Zöllner (1).
- 1881. Simony.
- 1883. Schlegel (2).
- 1906. Tietze.
- 1907. Sommerville (2).

Q3b. CONNEXION OF SURFACES.

- 1871. Betti.
- 1876. Riemann (1).
- 1890. Tonelli.
- 1892. Poincaré (1).
- 1895. Brunel (2).
- 1897. Picard (1, 2).
- 1898. Heegaard.
- 1899. Poincaré (2).
- 1901. Poincaré (2).
- 1906. Tietze.
- 1909. Hadamard.

Q3c. RELATIVE POSITIONS WHICH AFFECT TWO OR MORE CLOSED CURVES OR SURFACES.

- 1869. Kronecker.
- 1890. Dyck.
- 1905. Brunn.
- 1906. Tietze.

Q4. GEOMETRY OF SITUATION, OR GEOMETRICAL ARITHMETIC.

- 1891. Schlegel (2).
- 1894. Arnoux.
- 1895. Brunel (1).
- 1908. Arnoux.

Number of points, lines, &c., in S_n .

- 1901. Schoute (5).
- 1907. Sommerville (1).

Number of regions into which a given region can be divided by hyperplanes, &c.

- 1879. Pilgrim.
- 1897. Cahen.
- 1898. Curjel.
- 1901. Piccioli (1).
- 1905. Schoute (4).

Q4a. CONFIGURATIONS.

1879. Kantor.
 1884. Schubert (1), Veronese
 (2).
 1885. Hossfeld.
 1886. Hess.
 1887. Segre (7).
 1888. Segre (4).
 1896. Moore, Zindler.
 1898. Dumont.
 1901. Funck, Schoute (3).
 1902. Carp.
 1904. Lasker.
 1905. Carver.
 1906. Carver (1, 2).
 1907. Barrau (2), Sommerville
 (1).
 1908. Barrau (1-4).
 1909. Barrau, Burnside, Carver
 (1, 2), Ciani.

R. DYNAMICS, &c., IN NON-EUCLIDEAN SPACE AND SPACE OF n DIMENSIONS.**R1. KINEMATICS.****i. n DIMENSIONS.**

1866. Schläfli (1).
 1872. Jordan.
 1876. Beltrami.
 1880. Scheeffer.
 1888. Cesàro (2).
 1891. Schoute (2).
 1897. Landsberg, Muirhead,
 van Oss.
 1898. Craig, Muirhead.
 1900. Hatzidakis (1), Lipschitz.
 1901. Bromwich.
 1902. J. G. Hardy, James.
 1903. van Oss.
 1904. Brouwer (2).
 1906. Eiesland.
 1907. Laura.

Rotations in S_n .

1876. Beltrami.
 1880. Stringham (4).
 1884. Stringham.
 1889. Cole.
 1891. Schottky.
 1902. Jahnke, van Oss (1, 2).
 1903. van Oss.
 1904. Brouwer (1-3), Jahnke.
 1907. König.

j. NON-EUCLIDEAN.

1870. de Tilly (1).
 1873. Lindemann.
 1876. Beltrami.

1879. Ball.
 1880. Ball.
 1883. Ball (1).
 1884. Heath.
 1889. Burnside.
 1895. Burnside (1, 2).
 1898. Burnside (1, 2).
 1900. Kölmel.
 1901. Bromwich, Wood.
 1903. Hudson.
 1904. Demoulin.
 1906. Andrade (2).
 1908. Andrade.

R2. GEOMETRY OF MASSES.**i. n DIMENSIONS.**

1888. Sharp (8, 12).

Moments of inertia.

1882. Routh.
 1886. Cesàro.
 1887. Hoppe (1).
 1905. Berry, Mehmke, Schoute
 (1).

Centroid of a simplex. (*See* **K²¹**.)

g. NON-EUCLIDEAN.**R3d. THEORY OF SCREWS, &c.****a. n DIMENSIONS. (*Ref.* **R1i**.)**

1902. Vahlen (1).
 1907. König, van Oss.

β. NON-EUCLIDEAN.

1873. Clifford, Lindemann.
 1876. Clifford (2).
 1879. Ball.
 1881. Ball.
 1882. Ball.
 1883. Ball (2).
 1884. Buchheim (3), Heath.
 1898. Andrade (1).
 1899. Kotelnikov.
 1902. Vahlen.
 1903. Hudson.
 1907. Study.

R4. STATICS.**e. n DIMENSIONS.**

1888. Sharp (7, 8).
 1896. de Francesco.
 1898. Young.
 1899. Study, Young (1, 2).
 1901. Schoute (2).
 1902. van Oss (2).
 1906. Schoute (1, 2).
 1907. van Oss.
 1908. Del Re, Rath.
 1910. Del Re (1, 2).

i. NON-EUCLIDEAN.

- 1761. de Foncenex.
- 1869. Genocchi (2).
- 1873. Lindemann.
- 1877. Genocchi (2).
- 1897. Andrade (1, 2).
- 1898. Andrade (1, 2), Whitehead (1).
- 1899. Andrade, de Francesco (1, 2), Study.
- 1900. Andrade (2).
- 1902. Andrade.
- 1905. Liebmann (1).
- 1909. Rath.
- 1910. Del Re (2).

R5c. ATTRACTION AND POTENTIAL.

a. n DIMENSIONS.

- 1869. Kronecker.
- 1873. Schering (2).
- 1875. Cayley (2).
- 1881. Kronecker, Opitz.
- 1882. Tonelli.
- 1883. Poincaré (1), Tonelli.
- 1885. Biermann.
- 1886. Hoppe (2).
- 1887. Giuliani (1).
- 1890. Klein (4).
- 1896. Hobson.
- 1897. Dixon.
- 1898. Poincaré (2).
- 1901. Prasad.
- 1906. Brouwer (1-3).

β. NON-EUCLIDEAN.

- 1873. Fresdorf, Schering (2).
- 1881. Opitz.
- 1902. Liebmann (2).
- 1903. A. L. Dixon.
- 1906. Brouwer (2, 3).

Laplace's equation and Green's functions.

- 1886. α Riquier.
- 1887. α Giuliani (2).
- 1889. α Stieltjes.
- 1894. α Burkhardt.
- 1896. α Marcolongo.
- 1897. β Wirtinger.
- 1900. β Bianchi (2).
- 1901. α Giulotto.
- 1902. β Fubini (3).
- 1903. β Fubini (1).
- 1904. β Fubini (2).
- 1905. α Bocchetta (1).
- 1906. Quintili, α Watson.
- 1908. α Dall'Acqua.

R6c. GENERAL PRINCIPLES OF DYNAMICS.

 α . n DIMENSIONS.

- 1872. Mach.
- 1876. Lipschitz (3).

β. NON-EUCLIDEAN.

- 1870. Schering, de Tilly.
- 1883. Most.
- 1891. Killing.

R7. DYNAMICS OF A PARTICLE.

h. n DIMENSIONS.

- 1883. Killing (1).
- 1893. Stäckel (2, 3).
- 1899. E. Schultze.
- 1902. Ebert.

i. NON-EUCLIDEAN.

- 1873. Lipschitz.
- 1883. Killing (1).
- 1886. Neumann.
- 1902. Liebmann (2).
- 1903. Liebmann (2).
- 1905. Liebmann (1).

R8. RIGID DYNAMICS.

j. n DIMENSIONS.

- 1872. Lipschitz (1).
- 1873. Frahm (1), Schering (3).
- 1876. Clifford (1).
- 1883. Killing (1).
- 1889. Cesàro (1).
- 1899. Goodwin.
- 1902. Finzi, Stäckel (4).
- 1903. Mehmke (1).
- 1908. Rath.

k. NON-EUCLIDEAN.

- 1873. Schering (3).
- 1874. Clifford.
- 1883. Ball (2), Killing (1).
- 1884. Heath.
- 1889. Gravelius.
- 1897. Klein (4).
- 1899. de Francesco (2), Study.
- 1900. de Francesco (1-3), Study (1).
- 1902. Finzi, de Francesco (2), Stäckel (4).
- 1903. Cotton.
- 1905. Liebmann (1).

S. MECHANICS OF FLUIDS.

S1. HYDROSTATICS.

c. n DIMENSIONS.

d. NON-EUCLIDEAN.

S2. HYDRODYNAMICS.g. *n* DIMENSIONS.

1883. Siebert.

h. NON-EUCLIDEAN.

1902. de Francesco (1).

T. MATHEMATICAL PHYSICS.**T2a. ELASTICITY.**ζ¹. *n* DIMENSIONS.

1888. Ricci.

1889. Cesàro (2), Somigliana.

1896. Cesàro.

1898. Tedone.

1904. Havelock.

1907. Riquier.

ζ². NON-EUCLIDEAN.

1881. Beltrami.

1888. Cesàro (3), Padova (2),
Somigliana.

1889. Cesàro (2), Padova (2).

1894. Cesàro (3, 4).

T3. Light.**T3a. GEOMETRICAL OPTICS.** (*See*
Q2cγ.)**T3b. PHYSICAL OPTICS.**a. *n* DIMENSIONS.

1907. Garbasso.

U. ASTRONOMY.Measurement of parallax. (*See*
Q1aβ.)**V. PHILOSOPHY AND HISTORY.****V1a. Pedagogy, &c.****V1aα. BIBLIOGRAPHIES.**General. (*See* Introduction.)Euclid. (*Ref.* **V2bδ.**)

1887. Riccardi.

1901. Simon.

1908. Heath.

Theory of parallels.

1763. Klügel.

1835. Hill.

1838. Sohneke.

1859. Hoffmann.

1887. Riccardi.

1893. Zeuthen.

1895. Stäckel and Engel.

1899. Stäckel (1).

1901. Barbarin (4).

Non-euclidean geometry.

1878. Halsted.

1880. Vaščenko-Zacharčenko.

1899. Bonola.

1905. Withers.

Space of *n* dimensions.

1878. Halsted.

1886. Schlegel (1).

1892. de Galdeano.

Miscellaneous.

1889. Goursat (**K²4c**).1892. Klein (1) (**M⁵**).1896. Busse (2) (**Q1aβ**).1898. Hardcastle (**M⁵2**).1902. Gauss (**Q1aβ**).1906. Young (**J5b**).

1910. Sommerville (5).

V1aη. TEACHING OF GEOMETRY OF
***n* DIMENSIONS.**Treatises on geometry of *n* dimen-
sions.

1893. Killing (1).

1902. Schoute (1).

1903. Jouffret.

1905. Schoute (4).

1906. Jcuffret.

1907. Bertini.

V1aκ. TEACHING OF NON-EUCLIDEAN
GEOMETRY.

1891. Halsted (1).

1900. Andrade (1), Thieme,
Veronese.

1902. Frischauf, Halsted (9).

1904. Halsted (3).

1907. Enriques (3 (2)).

1908. Lietzmann.

Treatises on non-euclidean geometry.

1876. Frischauf.

1885. Killing.

1893. Killing (1).

1894. Hagen.

1901. Mannig.

1902. Barbarin (2).

1905. Liebmann (1).

1906. Bonola (1).

1907. Enriques (2).

1909. Vörös.

1910. Coolidge, Pascal, Vörös.

1911. Vörös.

Treatises on the foundations of geometry.

- 1882. Pasch.
- 1891. Veronese.
- 1893. Killing (1).
- 1897. Russell.
- 1899. Hilbert.
- 1903. Russell.
- 1904. Couturat (1).
- 1907. Enriques (2).
- 1909. Schur.

V1d. Logical principles and philosophy of geometry. (*Ref. Q1a.*)

Generalities.

- 1889. Bergson.
- 1890. Klein (1).
- 1891. Halsted (2).
- 1893. Halsted (3), Weber.
- 1894. Tannery.
- 1896. Čelpanov, Couturat, Hyslop, Lechallas (1), Schotten.
- 1897. Chandler, Faifofer, Kleinpeter, Schotten, Simon (1).
- 1898. de Galdeano, Laisant, Poincaré (1).
- 1900. Calinon (1, 2), Hölder, Poincaré (2, 3), Sorel, Vasiliev.
- 1901. Faggi, Milau, Palágyi, Russell (2, 3), de Tilly (1).
- 1902. Čelpanov, Geissler, Halsted (3), Mach, Natorp.
- 1903. Freycinet, Geissler (1, 2), Laudahn, Merchich, Palágyi, Reinecke, Richard, Russell, Wehner.
- 1904. Couturat (1, 2), Milhaud, Riehl (1, 2), Vailati.
- 1905. Nelson, Poincaré (3).
- 1906. Catania, Geissler (2, 3), Riesz.
- 1907. Brouwer, Combebiac (1), de Galdeano, Geissler, Enriques (3 (1)).
- 1908. Carus (1).
- 1909. Brouwer (1), Mannoury.
- 1910. Berkeley, Natorp, Whitehead and Russell (2).

Axioms of geometry. (*Ref. Q1a.*)

- 1866. Helmholtz.
- 1868. Helmholtz.
- 1870. Helmholtz (1, 2), Rosanes.
- 1871. Jevons.

1872. Becker, Clifford, Helmholtz, Hoffmann, Tupper.

1874. Worpitzky.

1875. Clebsch, Houël, Lewes, Tobias.

1876. Helmholtz (1, 2), Tannery.

1877. Becker (1), Erdmann, Günther (1, 2), Land.

1878. Helmholtz, Krause, Land, Weissenborn.

1879. Gilles, Helmholtz.

1881. Donadt.

1883. Carbonnelle, Jacobson.

1886. R. P.

1888. Milhaud.

1889. Communes, Renouvier.

1890. Heymans, Klein (1), Kofler, Lechallas (1).

1891. Dixon, Hyslop, Lindemann, Pietzker, Poincaré, Simon (1), Sorel.

1892. Pietzker, Renouvier.

1893. Couturat (1), Delbœuf (1).

1894. Smirnov.

1895. Dickstein, Straszewicz.

1896. Russell.

1897. Russell.

1898. Couturat, Dixon (1), Russell, Sutak, Tannery.

1899. Čelpanov, Poincaré (3), Russell, J. Schultz.

1900. Hölder, Poincaré (2), Seleznev.

1901. de Cyon, Enriques (2), Lechallas (4), Pieri (2).

1902. Poincaré (3).

1903. Frege, Gerstel, Korselt, Rueda, Russell, Wilson (3).

1905. Bogomolov, Combebiac (3).

1906. Baker, Frege, Meinecke, Nelson.

1907. Bogomolov, Richard, Whitehead (2).

1908. Bernstein, Combebiac (2, and Richard), Korselt, B. Levi, Poincaré (1, 3), Voss, Zeuthen.

1910. Hobson, Whitehead (1), M'Coll.

The nature of space.

1781. Kant.

1868. G. Engel.

1870. Becker.

1875. Funcke, Schmitz-Dumont.

1876. O. Liebmann.
 1877. Schmitz-Dumont.
 1880. Caspari, Gilles (1, 2),
 Schlegel.
 1881. Donadt, Stallo.
 1882. Roberts.
 1883. Most, Wundt.
 1884. Jahn.
 1885. Wehr.
 1888. Bocksch, La Rive.
 1889. Bellermann, Calinon,
 Cockle, La Rive, Lech-
 alas.
 1893. Calinon, Couturat (1, 2),
 Delbœuf (1, 2), Lech-
 alas.
 1894. Cinger, Delbœuf, Lech-
 alas.
 1895. Dreyer, Poincaré (2).
 1896. Del Re (2), Schiller.
 1897. Poincaré.
 1898. Goldschmidt, A. Muller.
 1901. de Cyon (1, 2).
 1902. Kirschmann, Laurent (1),
 Mecklenburg, Pietzker
 (1), Poincaré (4).
 1903. Boucher (1, 2), Carus,
 Hausdorff, Poincaré (1),
 Varisco.
 1904. Cantoni, Dietrich.
 1905. Bogomolov, Lechalas,
 Pailler, Poincaré (2),
 Withers.
 1906. Pozdena.
 1907. Borgmann, Saminskij,
 Ulrich.
 1910. Halsted (2).

Conception of space as an extended
 manifold. (*Ref. J5b, Q1aβ.*)

1866. Riemann.
 1877. Erdmann.
 1878. Gosiewski.
 1879. Caspari.
 1881. Donadt, Stallo.
 1883. Ball (1).
 1889. Mlodzejevskij.
 1905. Schlesinger (1).
 1907. Enriques (2).

Physiological, &c., space.

1764. Reid.
 1884. Henrici.
 1895. Poincaré (2).
 1901. Mach.
 1902. Mach, Poincaré (4).
 1903. Poincaré (1).

1905. Mach, Poincaré (2).
 1906. Enriques, Guérout,
 Lechalas, Weinstein.

Space and the semi-circular canals of
 the ear.

1901. Couturat, de Cyon (1, 2),
 Lechalas (1).
 1902. de Cyon.
 1903. Poincaré (1).
 1906. Saleeby.
 1908. de Cyon.

The number of dimensions of space.

- 2nd cent. Ptolemy (1).
 1712. Leibniz.
 1746. Kant.
 1856. Gauss (*see* Sartorius).
 1875. Funcke.
 1877. Erdmann.
 1878. Gilles, Schmitz-Dumont.
 1879. Michaelis.
 1881. Müller.
 1882. Jenrich.
 1889. Lechalas.
 1890. Nagy (3).
 1893. Carus.
 1895. Dreyer.
 1901. Couturat, de Cyon (1),
 Lechalas (1).
 1902. Kirschmann, Natorp,
 Pietzker (1, 2), Poin-
 caré (4).
 1903. Poincaré (1), Rabino-
 vitch, Richard, Smith.
 1904. Lagrange (3).
 1905. Poincaré (2).
 1906. Lechalas, Saleeby, Wein-
 stein.
 1907. Geissler.

Possibility of motion of rigid bodies.

1866. Helmholtz.
 1868. Helmholtz.
 1874. Worpitzky.
 1892. Lie (3).
 1896. Russell.
 1898. Lechalas.
 1900. Bustelli.
 1902. Poincaré (4).
 1904. Bonnesen (1, 2).

Attempts to prove from philosophical
 principles that euclidean geometry
 is the only possible geometry.

1860. Delbœuf.
 1870. Becker.
 1875. Becker.
 1897. Delbœuf.

1902. Pietzker (1).
 1903. Delsol.
 1904. Lechallas (2).
 1905. Delsol, Milau.
 1908. Hill.
- "Atomic" geometry.
 1891. Bonnel.
 1895. Bonnel.
 1899. Bonnel.
 1900. Bonnel.
 1902. Bonnel (1-4), Lagrange.
- V2b. History.**
- Axiom of Archimedes.
 1882. Stolz.
 1906. Zeuthen (1).
 1908. Simon.
- Mechanics in S_n .
 1902. Stäckel (4).
 1903. Stäckel (3).
- V2b α . SPACE OF n DIMENSIONS.**
- General histories.
 1886. Schlegel (1).
 1887. Loria (2).
 1888. Dickstein.
 1910. Majcen.
- Miscellaneous.
 1879. Zöllner.
 1881. Zimmermann.
 1886. Gibbs.
 1888. Dickstein.
 1896. de Galdeano.
 1904. Pierpont.
 1905. Eneström.
- V2b β . NON-EUCLIDEAN GEOMETRY.**
- General histories.
 1867. Forti.
 1894. Reyes y Prósper (1).
 1895. Mansion (1).
 1896. Mansion (5).
 1899. Čelpanov.
 1902. Frankland, Russell.
 1904. Kagan (2).
 1906. Bonola (1).
 1907. Kagan, Bonola (*see* Enriques 3 (8)).
- Contained in general histories of mathematics.
 1887. Loria (2).
 1890. Fink.
 1893. Zeuthen.
 1894. Cajori.
 1904. Pierpont.
- Special topics.
 1890. Mansion (1), Picard.
 1892. Mansion, Picard.
 1893. M'Clintock.
 1894. Halsted (1).
 1895. Mansion (3).
 1898. Mansion (3).
 1899. Halsted (3).
 1901. Mansion (2), Stäckel.
 1902. Mansion (2).
 1903. Segre.
 1907. Varicak (2).
 1910. Sommerville (4).
- Miscellaneous.
 1891. Mansion (1).
 1893. Karagiannides.
 1894. Halsted (2).
 1896. de Galdeano, Halsted (2).
 1899. Halsted (1, 2).
 1902. Halsted (8).
 1903. Cantor, Eneström (1, 2).
 1904. Hinton (2), Rosanes.
 1908. Fano (2), Kagan.
- V2b γ . THEORY OF PARALLELS.**
- General histories.
 1763. Klügel.
 1789. d'Alembert.
 1802. Voit.
 1808. Klügel.
 1824. Camerer.
 1834. Thompson.
 1838. Sohncke.
 1840. Anon.
 1885. Chrystal.
 1895. Stäckel and Engel.
 1896. Mansion (4-6).
 1900. Bonola (2).
 1905. Withers.
 1906. Bonola (1).
 1907. Kagan, Bonola (*see* Enriques 3 (8)).
 1908. Bobynin, Heath.
 1910. Frankland.
- Miscellaneous.
 1758. Montucla.
 1759. d'Alembert.
 1775. Büsch.
 1781. Hindenburg.
 1792. Castillon.
 1828. Lardner.
 1867. Grunert.
 1888. W. W. R. Ball.
 1891. Halsted (*see* Lobachevsky).
 1892. Suter (2).

1895. Dellac.
 1900. Janssen van Raaij.
 1902. Ricci (2).
 1905. Bonola (1, 2), Vailati (2).
 1906. Simon.
 1907. Langenkamp.

V2b5. BIOGRAPHIES AND SPECIAL NOTICES.

Barbarin.

1908. Halsted (2).

Beltrami.

1900. Bryan, Cremona, Lévy,
 d'Ovidio.
 1901. Loria.
 1902. Halsted (1).

The Bolyai, father and son.

1867. Schmidt.
 1889. Konez.
 1891. Halsted (*see* Bolyai).
 1894. Reyes y Prósper (2).
 1897. Engel and Stäckel (2),
 Mansion (7).
 1898. Bedöházy.
 1903. Cantor, Eneström (1, 2),
 Schlesinger (4).

Bolyai Farkas.

1884. Szily.
 1896. Halsted (3).
 1897. Stäckel (1).
 1899. Schmidt and Stäckel.
 1902. Schlesinger (1).
 1907. Szabó.
 1909. Szabó.

Bolyai János.

1885. Szily.
 1897. J. Bolyai (2), Schmidt.
 1898. Halsted (6), Schmidt.
 1901. Stäckel.
 1902. Mansion (2), Stäckel (2),
 3).
 1903. Réthy, Schlesinger (1, 2),
 Stäckel (1, 2).
 1904. Darvai.
 1910. Halsted (1), Szabó.

Caporali.

1889. Loria (2).

Cayley.

1895. Forsyth, Halsted (1).

Euclid and his works.

1879. Halsted.
 1880. Weissenborn.
 1884. Tannery.
 1890. Mansion (2).

1892. Suter (1).
 1901. Simon.
 1902. Frankland, Smith.
 1904. Heiberg.
 1905. Frankland, Vailati (1).
 1908. Heath.

Principal editions of Euclid. (For a collection of editions, translations and commentaries on Euclid *see* Riccardi 1887, Simon 1901, and Heath 1908.)

12th cent. Athelhard.

1482. Euclid.
 1533. Euclid.
 1557. Peletier.
 1570. Billingsley.
 1572. Euclid.
 1574. Clavius.
 1594. Nasiraddin.
 1705. Scarburgh.
 1756. Simson.
 1814. Peyrard.
 1824. Camerer.
 1828. Lardner.
 1883. Euclid.
 1893. an-Nairizi.
 1899. an-Nairizi.
 1905. Frankland.

de Foncenex.

1869. Genocchi (1).

Gauss.

1856. Sartorius.
 1877. Schering.
 1879. Schering.
 1896. Stäckel.
 1897. Engel (2), Stäckel (1).
 1899. Mansion (3), Schmidt and
 Stäckel.
 1900. Halsted (1), Stäckel (2).
 1901. Mansion (2).
 1903. Cantor, Eneström (1, 2).
 1904. Halsted (1).
 1908. Mansion (1).
 1909. Szabó.
 1910. Carslaw (2), Sommer-
 ville (4).

Halsted.

1900. Halsted (2).
 1903. Alasia.

Helmholtz.

1895. Koenigsberger.
 1904. Riehl (1, 2).

Hoüel.

1897. Halsted (1).

Lambert.

1829. Huber.
 1893. Halsted (1).
 1895. Halsted (3).
 1899. Stäckel (2).
 1905. Schur.

Lie.

1899. Halsted (4).

Lobachevsky.

1868. Janiševskij.
 1870. Höüel (1).
 1893. Reyes y Prósper, Sokolov, Vasiliev (1), Anon. (2).
 1894. Dolbnia, Isnoskov (*see* Anon.), Lachtin, Litvinova, Plamenevskij, Vasiliev (1, 3), Wagner.
 1895. Archimovič, Halsted (2).
 1896. Vasiliev, Weyr, Anon. (1, 2).
 1897. Vasiliev (1, 2), Weyr, Anon.
 1898. Engel (2), Halsted (7).
 1899. Anon.
 1902. Modzalevskij, Anon. (2).
 1905. Halsted (1).
 1907. Varicak (1).

Minkowski.

1910. Hilbert.

Riemann.

1894. Klein (2).

Saccheri.

1889. Beltrami, d'Ovidio.
 1890. Mansion (1).
 1893. Vasiliev (2).
 1903. Favaro, Vailati.

Schering.

1892. Mansion.

Schmidt.

1901. Halsted (3).
 1902. Stäckel (1).

Schweikart.

1905. Tichomandrickij (2).

Sylvester.

1889. Cayley (2).

Taurinus.

1899. Stäckel (3).

de Tilly.

1895. Mansion (3).

Vasiliev.

1897. Halsted (2).

Wachter.

1900. Stäckel (1).

The Lobachevsky prize.

The following are the awards and honourable mentions.

- I. (1897). LIE. (Cesàro, Fontené, Gérard.)
 II. (1900). KILLING. (Binder, Whitehead.)
 III. (1903). HILBERT. (Barbarin, Lemoine, Pieri, Study.)
 IV. (1906). —. (Levi.)

1895. Anon.
 1896. Anon. (3).
 1898. Halsted (2), Vasiliev, Anon. (1, 2).
 1901. Anon. (1).
 1902. Vasiliev and Suvorov.
 1904. Halsted (4), Laisant, Mansion, Peano, Poincaré (3), Zejligier, Anon.
 1906. Anon.

The Bolyai prize.

- I. (1906). POINCARÉ. (Hilbert.)
 II. (1910). HILBERT.

1905. Halsted (2).
 1906. Rados.
 1911. Poincaré.

X9. Models.

Regular polytopes of four dimensions.

1884. Schlegel.
 1886. Schlegel (2, 3).
 1892. de Galdeano, Anon.
 1893. Schlegel.
 1897. Heyl (2).
 1903. Schilling.
 1907. Stott (2).

Surfaces of constant curvature.

1877. Brill.
 1892. Anon.
 1903. Schilling.
 1906. Bonola (2).

X10a. EXTENSION OF MAGIC SQUARES AND CUBES TO n DIMENSIONS.

1882. Harmuth.
 1892. Schlegel.
 1894. Arnoux, Laisant.

ALPHABETICAL INDEX OF SUBJECTS.

- Absolute**, theory of the, **Q1ea**.
- Algebraic curves** **M⁵**, **Q1(M¹)**; — surfaces **Q1(M²)**; — varieties **M⁶**, **M⁷**.
- Altitudes of a simplex** **K²¹**.
- Analysis situs** **Q3**.
- Analytical geometry** **K²²**, **L³**, **M**, **N**, **Q1(K)**.
- Angle**, notion of, **Q1a**; sum of the —s of a triangle, **K²¹⁰**, **Q1aa**; parallel —, **Q1(K20)**; division of an —, **Q1(K21b)**; *n*-dimensional —, **K^{24a}**; — between hyperplanes, **K²**.
- Anharmonic ratio**, **K²³**, **Q1(K7)**.
- Applicable surfaces**, **Q1(06k)**; — varieties, **O²**.
- Applications of hyperspace**, **Q2c**; — of non-euclidean geometry **Q1**, **Q1(K9b)**.
- Archimedes**, axiom of, **Q1a**, **V2b**.
- Ares**, **Q1(K10c)**, **O2c**.
- Area**, plane, **Q1a**; — of polygons, **Q1(K9aa)**; equivalence of two polygons, **Q1a**; — of surfaces, **Q1(05b)**; — of a triangle, **Q1a**, **Q1(K1d)**; — of a circle, **Q1(K10c)**; infinite —s, **Q1aa**.
- Asymptotes of a conic**, **Q1(L¹³)**.
- Atomic geometry**, **V1d**.
- Attraction**, **R5c**.
- Ausdehnungslehre**, **B12c**.
- Automorphic functions**, application of, to algebraic curves, **M⁵¹**; application of non-euclidean geometry to —, **Q1**, **Q1(K9b)**.
- Axioms of geometry** treated philosophically, **V1d**; systems of —, **Q1a**; — of parallels, **Q1aa**.
- Barycentric coordinates**, **K²²**.
- Beltrami**, **V2bδ**.
- Bibliographies**, **V1aa**.
- Bicursal curves**, **M^{54b}**.
- Binary forms**, **Q1eδ**.
- Biographies**, **V2bδ**.
- Biquaternions**, **B12e**.
- Birational transformations**, **M^{67f}**, **P²⁴**.
- Bolyai**, geometry of, **Q1b**; biography of —, **V2bδ**; — prize, **V2bδ**.
- Bonnet**, transformation of, **P^{26b}**.
- Calculus of variations**, **Q1ay**.
- Cantor**, point groups (Punkt-Mengen, Ensembles), **J5b**, **P²⁵**.
- Caporali**, **V2bδ**.
- Caustics**, **Q1(02qβ)**.
- Cayley**, **V2bδ**; — -Klein projective metric, **Q1ea**.
- Central orbits**, **R7**.
- Centre of a quadric**, **L³⁴**.
- Centroid**, **R2**; — of a simplex, **K²¹**; — of a polytope, **K^{24d}**.
- Circles connected with a triangle**, **Q1(K2, 10)**; systems of —, **O²²**, **Q1(K11)**.
- Circumscribed circle**, **Q1(K2a)**; — cone, **L³⁶**; — hypersphere, **K²¹**; — quadrilateral, **Q1(K8c)**; — sphere, **Q1(K16b)**.
- Classification of conics**, **Q1(L^{11a})**; — of curves, **M⁵⁵**; — of quadrics, **L^{31a}**, **Q1(L^{21a})**.
- Clifford's parallels**, **Q1(K13a)**; — surface, **Q1(L²²)**.
- Codazzi**, formulae of, **O²²**.
- Collineation**, *see* homography, **P²¹**.
- Combinatorial analysis**, **Q2cβ**.
- Complex quantities**, **B12**; — variable in **S_n**, **Q2**; application of — variable to non-euclidean geometry, **Q1**; representation of — variables, **B12a**.

- Complexes, N^5 , $Q1(N^1)$.
 Cones, K^{25b} , L^2 , $Q1(K15)$; circumscribed —, L^{36} .
 Configurations, $Q4a$.
 Confocal conics, $Q1(L^{119})$; — quadrics, $Q1(L^{210})$, L^{310} .
 Conform representation, $Q1, e\beta$, P^23 .
 Congruence (=equivalence) of figures, $Q1a$.
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 Contact transformations, P^26e , $Q1(P6e)$.
 Continuity of manifolds, $J5b$; axioms of —, $Q1a$.
 Continuous groups, $J4f$, $Q1a\gamma$, $Q2$.
 Continuum, $J5b$.
 Coordinates, K^22 , $Q1(K6)$; curvilinear —, O^22 .
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 Cremona transformations, P^24 .
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 Cubic curves, $Q1(M^15)$; — varieties, M^63 , M^73 .
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 Cyclides, M^64 , $Q1(M^24)$.
 Cylinders, K^25a , L^32 , $Q1(K15)$, L^22 .
 Defect of a triangle, $Q1a\alpha$.
 Deficiency of a curve, M^61a , 4; — of a surface, M^61b , 7c.
 Definition of point, $Q1a$; — of straight line, $Q1a$; — of plane, $Q1a$; — of parallel lines, $Q1a\alpha$.
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 Degenerate absolute, $Q1ea$.
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 Desmic tetrahedra, M^65 .
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 Differential equations, $Q2c\beta$; — equation of quadratic varieties, L^{314} ; — forms, $C4d$; — invariants, O^22 ; — geometry, O^2 , $Q1(O)$; — basis for geometry, $Q1a\beta$.
 Dihedral angle, $Q1(K13a)$.
 Dilatation, $T2a$.
 Dimensions of space, $V1d$; space of infinite —, $Q2$.
 Direction, $Q1a\alpha$.
 Discontinuous geometries, $Q1d$; — groups, $J4e$, K^24c .
 Discrete geometries, $Q1d$.
 Distance, relation between — of given points, K^2 , $Q1a\gamma$, $Q1(K1b)$.
 Division of an angle, $Q1(K21b)$; — of the plane by polygons, $Q1(K9b)$; — of space by polyhedra, $Q1(K14g)$; — of S_n by polytopes, K^24g .
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 $V1a\alpha$, $V2b\delta$; postulate or axiom
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Euler's formulae for polyhedra,
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Finite distances, $Q1a\gamma$; — geometries,
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Focal properties of a conic, $Q1(L^17)$.

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Geometry, analytical, K^2 , $Q1(K)$;
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 $Q1a$, $V1d$; descriptive —, K^212 ,
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Helix, M^8 , O^21 .

Helmholtz, $V2b\delta$.

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 Lie's continuous groups, J4f.
 Light, theory of —, T3b.
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CORRECTIONS.



- Page 53, line 9 from top, *for* "HOGBEN," *read* "Hogben,"
,, 60, ,, 1 ,, ,, *for* "rationnels." *read* "rationnels."
,, 66, ,, 15 ,, ,, *for* "**Fiedler**." *read* "**Fiedler**, W."
,, 143, ,, 3 ,, foot, *for* "ПѢ" *read* "ОѢ"
,, 167, ,, 3 ,, top, *for* "GORDAN" *read* "Gordan"
,, 198, ,, 5 ,, foot, *for* "uno" *read* "una"
,, 232, ,, 2 ,, top, *for* "London," *read* "Berlin,"
,, 235, ,, 31 ,, ,, *for* "Wolfing," *read* "Wölffing,"

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